DISCOVERY

Monthly Notebook

Memory of the Prodigy
Those Systemic Insecticides
DDT Fails against Korean Lice
The Voice of the Chaffinch
Scale Model of the Thames
The Alchemical Origins of Chemistry

The Chemical Revolution
F. E. WARNER, B.Sc., M.I.Chem.E.

Control of the Weather
RICHARD BLAIR

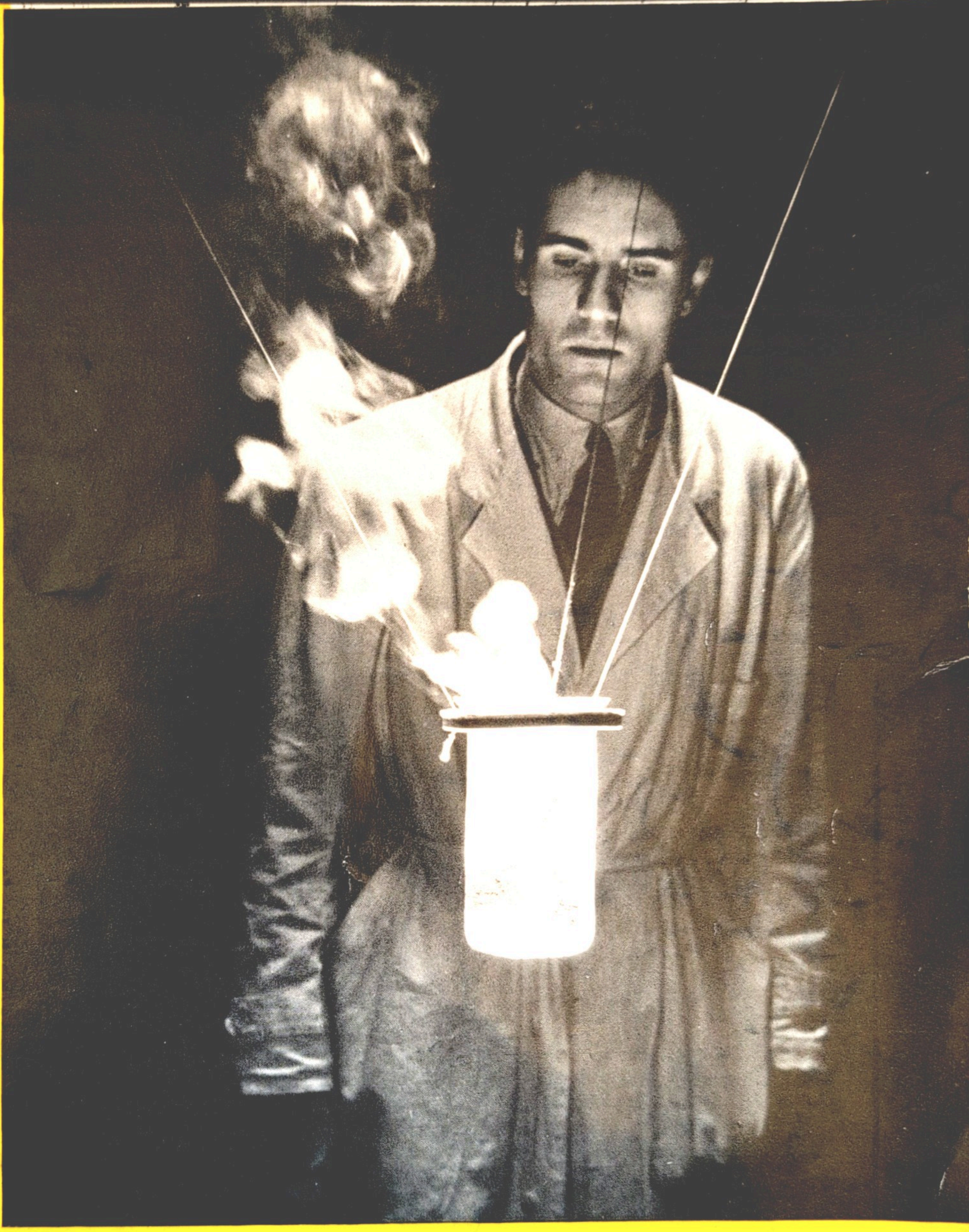
The Palace of Discovery

Energy in the Future
PROF. F. E. SIMON, F.R.S.

Vivipary in Fishes
CHAPMAN PINCHER

Far and Near

The Bookshelf



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10

APRIL
1952
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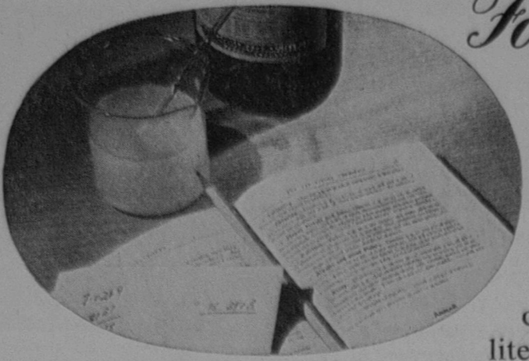

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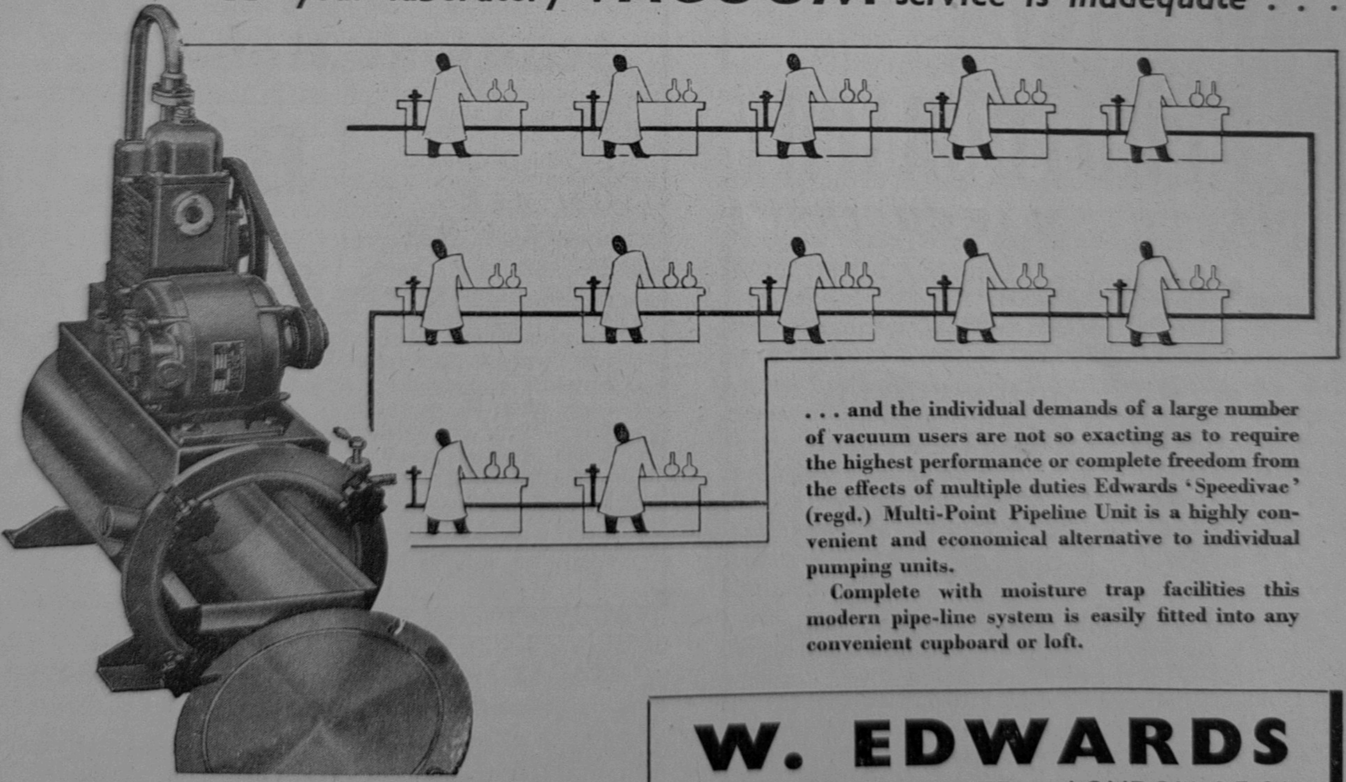

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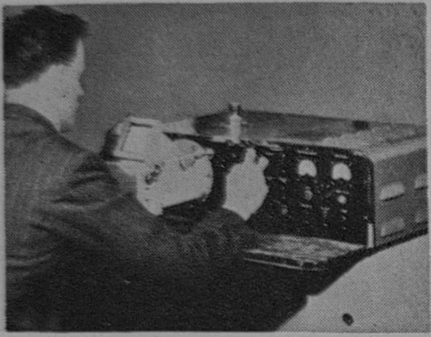

Fig. 1. Close-up view of the control desk and camera of the Metrovick electron microscope Type EM4.

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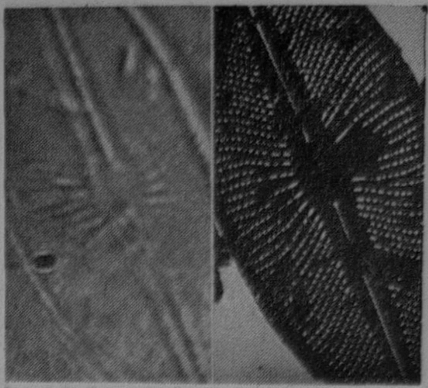

Fig. 2. In these microphotographs of diatoms the clarity of definition obtainable with the electron microscope is shown by the right-hand photograph. The picture on the left shows definition obtainable with optical instrument under the same conditions.

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THE MAGAZINE OF SCIENTIFIC PROGRESS

April, 1952 Vol. XIII. No. 4

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The Progress of Science

Memory of the Prodigy

REMEMBERING is a mysterious human activity without a moderate amount of which social life would be impossible. It is an activity familiar to all of us. Yet very little is known about it in a general way and there is even today, after a century or so of psychology, no satisfactory theory of memory. As the Oxford experimental psychologist, O. L. Zangwill, writes: "The cerebral basis of memory remains an enigma." One thing can be asserted, however, with some assurance: remembering has the attributes of a specific skill rather than of general mental ability. It can be considerably improved on specific activities by training. It can be independent of intelligence. Furthermore, the degree of natural untrained memory is inborn and not acquired during lifetime.

All these facts are brought out in a book just published, a book written by a modest author whose only care is to present within one book the known facts about numerous 'lightning calculators' and other prodigies—*Mental Prodigies*, by Fred Barlow (London, Hutchinson's Scientific and Technical Publications, 1951, 256 pp., 12*s*. 6*d*.).

The first chapter lists nineteen calculators and gives some details of their lives and achievements. Twenty-four miscellaneous examples in brief are then mentioned. Of the nineteen, five were known to be stupid. Jedediah Buxton (1702–72), for instance, had at maturity the mind of a child of ten. Yet when presented with the problem of calculating the number of cubic eighths of an inch in a body whose three dimensions were 23,145,789 yards, 5,642,732 yards, and 54,965 yards, he worked it all out accurately in his head. Even more remarkable is Oscar Verhaeghe, a Belgian. In 1943 he was referred to as an adolescent of seventeen with the mental age of a babe of two years. He was examined by a committee of savants, including mathematicians. He cubed 689 in six seconds, gave the fourth power of 1246 in ten seconds and raised 9,999,999 to the fifth power in a minute. Another five of the nineteen were uneducated. On the other hand, a number of the remaining nine were well educated and achieved great things. There was Ampère, for example, and there was Gauss, who when not quite three years old followed mentally a calculation of his father's and detected a mistake in the answer. He entertained the court of the Duchy of Brunswick with his calculations when he was fourteen years old. Not intelligence or good birth or education or mature achievement was common to all the nineteen. What they had in common was an interest in figures and a prodigious memory. In the case of the unintelligent ones this specialised interest was helped by their ignorance of other matters. The fact that some of them were youthful prodigies and yet lost their powers is accounted for by the extension of their interests as they matured. In fact, the author contends that many a young fellow could attain to the eminence of some of these calculators if he would start young and concentrate on numbers. All that is required is the ability to count and a memory for numbers. The author, himself a considerable performer in feats of a calculating kind, even gives the short-cuts and dodges by means of which one can answer questions like: "What day of the week was 21 October, 1805?" (It was a Monday.)

In another chapter the author discusses some of the great memorisers, such as that Bottle full of dates known on the halls as Datas and not forgetting our own contemporary Leslie Welch. Again the point emerges that the outstanding memory is not a matter of general education or good birth. W. J. M. Bottle, for example, was in turn a newspaper boy, an errand boy, and a 'striker' in the blacksmith's shop at the Crystal Palace Gas Works. On the other hand Mr. Welch is general manager of a weekly sports journal and was educated at a well-known London secondary school.

Mr. Barlow extends his facts from calculators and memorisers to chess players and musical prodigies. He writes: "There is a close resemblance between calculators and chess prodigies. In each case, we have a wide variation of powers from the highly skilled man of general all-round ability to the comparatively illiterate person with a one-track mind." Again, an American psychologist, A. A. Cleveland, is quoted as saying: "At the same time, the cases of *idiots savants* in various forms of mental activity and, amongst others, in chess playing, prevent the inference that skill in chess is a universally valid index of high mental endowment." Details were given by this psychologist of a chess player of fair ability who was feeble-minded and an inmate of an American asylum. Once more the important point emerges that memory is one of the most important factors in the playing of chess, for the more games a man plays, the more he knows of the moves and counter-moves.

In music, too, the same facts emerge, though here there are additional factors. The memory of a piece of music, says one psychologist, is in the hands and brain, not the mind. The chief characteristics of the musically precocious are not sensibility or creativity but memory and manual dexterity. Furthermore, musical prodigies come from musical families. Here again is the insistence on hereditary factors, and the home environment.

Mr. Barlow's book is the result of great industry and love—some of the prodigies mentioned he has investigated himself. It could be improved by some pruning to remove what is merely hearsay, however well established, and to take away irrelevancies. It could be reorganised to make a more consistent classification. The rearranged book would then be more acceptable to the scientist, though it would undoubtedly lose in entertainment. It is, for example, entertaining to learn that Datas sometimes planted stooges in the audience. The duty of one stooge was to ask Datas the date of Kruger's vaccination. The answer came at once: "On March 15, 1826—and it took in four places—is that right, sir?" This, says Mr. Barlow, rarely failed to bring the house down.

As it is, the book provides data about prodigies and in doing this gives much food for thought among those who are interested in the working of the human brain. At the same time it debunks much of the nonsense written about phenomenal people like chess players and calculators. It is seen that many of these achievements, so often regarded with hushed awe, can be repeated even by an idiot.

Those Systemic Insecticides

MUCH RECOMMENDED of recent years have been the organo-phosphorous insecticides. Effective they certainly are against insects, but readers will recollect our reservations about them which were dictated by the inevitable hazards involved in their indiscriminate use. In fact, we long ago warned our readers that they are generally too toxic for use except by specialists, and hence they should be blacklisted by farmers and gardeners. We tried one of them last year, and we found that it certainly killed off a heavy brood of blackfly infesting a bed of nasturtiums, but quite frankly the stuff gave us the 'creeps'. Our impression is that although it did a good job, it was not so effective as the natural living enemies of blackfly, and we have it on our conscience that it killed nearly as many birds as aphids—a bad thing, as birds naturally help to keep aphids under control.

The same issue is taken up in *Nature* (1.3.52, p. 345), in an article by W. N. Aldridge and J. M. Barnes of the M.R.C. Unit for Research in Toxicology, Carshalton, Surrey. This article describes progress made in the search for effective insecticides less poisonous to mammals than TEPP, Parathion, and OMPA.*

The toxicity of these phosphate insecticides is apparently related to the fact that they 'poison' enzymes such as cholinesterase. *Pure* Parathion† is safer relatively speaking, but usually this insecticide contains a chemical called *p*-nitrophenyl diethyl phosphate (*E.600*) which strongly inhibits cholinesterase.

Yet so far as live mammals are concerned pure Parathion is almost as toxic as any of its isomers. Another organo-phosphorous insecticide (octa methyl pyrophosphoramide, *E.838*), which apparently does not poison cholinesterase in test-tube experiments, undergoes some strange transformation in the body of mammals and is changed in the liver into a very powerful inhibitor of cholinesterase: somewhat unexpectedly rabbits prove to be less susceptible to this inhibitory effect than rats. The two Carshalton researchers conclude that: *In comparing the activities of a series of compounds effective as inhibitors of cholinesterase, special care must be taken that the materials are free from traces of contaminants possessing activity against the enzyme several orders greater than the preparations being examined. It may be impossible to detect the presence of such impurities by chemical means.*

It seems probable that many of the compounds used, or proposed for use, as insecticides do not become toxic for mammals until they have been attacked by some metabolic system within the mammal. This fact lends hope to the possibility that compounds will be discovered which the insects, but not the mammals, will convert into poison for themselves.

Our conclusion is that farmers and gardeners would be well advised *not* to touch these insecticides until a great deal more research has been done on them. This year we shall use them for one job and one job only—for killing the insects infesting the various commercial samples of John Innes compost we have bought, and which we were surprised to find full of thrips and other pests—a sure sign that the compost had never been properly sterilised. If this proves to be a bad year for insect pests, we shall rely on such natural and well-tried insecticides as pyrethrum, derris and nicotine—and one safe and very old-fashioned insecticide, namely very fine dust (e.g. the dust obtained by sieving road-sweepings, by sieving ash from a domestic boiler or domestic grate, or by drying garden soil). Such dust applied in the usual way to a rose tree covered with greenfly proves to be a most effective insecticide, the insecticidal action being due to the fact that the insects' chitinous 'skin' is scratched by the dust and this abrasion leads to so high a loss of water from the insects' bodies that they die of sheer dehydration! (This mechanism was studied at the Imperial College of Science by Prof. H. V. A. Briscoe and his co-workers, though they appear to have been unaware that their insecticidal technique has been used for centuries by keen amateur gardeners.)

DDT Fails against Korean Lice

THE American journal *Chemical Engineering* report a strange failure of DDT in Korea. Up till now it has been considered the ideal material for controlling body-lice, and hence the transmission of typhus, but now it appears that DDT has practically no effect on Korean lice. Tests have shown that another insecticide, called Lindane (*syn.* Gammexane), is the answer and one million pounds were delivered in December for the use of troops in Japan and Korea.

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* OMPA (octa methyl pyrophosphoramide) is also known as SCHRADAN; it takes its name from DR. GERHARD SCHRADER, chemical-warfare expert of the I.G. Farben factory at Leverkusen.

† Seven known fatal casualties due to Parathion are recorded from the U.S.A., and more than 200 cases due to organo-phosphorous insecticides have been reported. In spring 1950 they killed 14 people in Brazil.

The Voice of the Chaffinch

THE characteristic springtime sound of our English countryside is not really the blackbird's or the thrush's song but the vibrant song of the cock chaffinch, a very common bird. He is a gay little fellow in his blue-grey cap and red breast and somewhat exaggerated white shoulders. And his song—to be distinguished from the 'spink spink' call-note—is as gay as he. It is short—lasting only a few seconds—and is repeated some half a dozen times a minute. It ends with an accelerated cadenza and is so characteristic that no observant person will fail to recognise it among all the bird-songs he hears. (Anyone ignorant of its cheerful protest can learn it in a few minutes from Ludwig Koch's records.)

When chaffinches start to sing in February, some of them fail to produce the final flourish. It seems that the young birds hatched the previous summer have to learn their song by imitation before they are note-perfect. Many other birds have characteristic songs and it has long been an undecided general question whether a bird's song is innate or acquired. Daines Barrington, English lawyer and naturalist of the eighteenth century, asserted that the song of all birds was learned. But today we know that this is too simple a generalisation, and in fact Barrington observed only skylarks, linnets, nightingales and robins, all of which do have to learn their songs. Heinroth pointed out in 1924 that there is considerable difference between the ways of distinct species, the song being inborn in some and learned in others. Recently Holger Poulsen of the Copenhagen Zoological Gardens has reported fully on his special investigations into the chaffinch song. So at last there is evidence that is acceptable to scientists.

Mr. Poulsen in 1946 took two male chicks about six days old and reared them in isolation in a room where they could not hear other chaffinches. In February of the following year, and after a week or so of twittering, they began to sing loudly. "They produced an imperfect version of the normal song consisting of short piping notes repeated in a quick rhythm followed by a hoarse buzzing. This inborn song was of about the same length as the normal song." At the end of the song there was a tendency to a flourish but it did not resemble the normal ending (described above as an accelerated cadenza). Mr. Poulsen also noted that not only was it evident that this cadenza had to be learned but he knew that it was just in this part of the chaffinch song that there was most geographical variation. (This lends colour to Ludwig Koch's assertion that once in Kew Gardens he heard a chaffinch sing and at once recognised it as a Belgian bird.)

In the middle of February the two young birds were moved to a position in which they could hear chaffinches in the woods and hedgerows outside. At the same time a linnet was in a cage near by. The result was that the birds imitated some of the linnet's notes but as soon as they clearly heard the outdoor chaffinches this imitation ceased and only the song of their species was learned. Within a fortnight they were singing the normal chaffinch song. Mr. Poulsen's conclusion was, therefore, that the chaffinch song is partly innate and partly learned.

The next question was: *when* does the normally free chaffinch learn the part that has to be learned? In September 1948 two young male chaffinches were caught. They were moulting prior to the arrival of winter plumage. Obviously these young birds, having been hatched in June, had been able to hear the normal adult song for at least a month. After capture they were kept isolated where they could not hear other chaffinches. The coming of the following spring was no doubt eagerly awaited, for on the behaviour of these two birds in February 1949 would depend the answer to the question already mentioned. Accordingly an observer listened keenly from January onwards. The birds began to sing at the beginning of February, faintly and imperfectly. It was March before they began to sing loudly, the lateness being assumed to be due to the faintness of the light in their room so that the lengthening of days in February was hardly perceptible. When they did sing aloud, their song was exactly that of the two other birds that had been reared from the chick stage in isolation two years earlier. At the beginning of May they were put outdoors near the territory of two free cock chaffinches. Despite this they never learned the chaffinch song. Nor did they in 1950. The inference is that every young cock chaffinch learns that part of the song that is not inborn in its first early spring when it begins to sing itself. This inference is supported by evidence from other workers, who have shown that if the first song learned is that of another species—achieved by not allowing the young bird to hear a chaffinch—then the normal song is never afterwards acquired.

Experiments on similar lines with other species showed that many of them develop in a different way. For example, the reed-bunting's song is quite innate whereas the linnet's has to be completely learned. The skylark learns its song. The wood-warbler's song is innate.

Against Mr. Poulsen's conclusions it has been contended that birds reared in captivity do not get into reproductive mood and that this accounts for their imperfect songs. But he points out that in fact reared birds do produce perfect songs once they have been allowed to hear adult birds in full song and if this exposure to example happens in the first spring. In addition, adult males in captivity produce their normal song at about the same time as those at liberty outside. Nevertheless, it was worth examining the effect of male sex hormone to see if it accelerated the production of song. It was injected into males well out of the reproductive season, actually in the December-January period. They began to sing imperfectly after three injections and their song was fully developed after the fourth. The conclusion was therefore that the first imperfect song in any cock chaffinch is the result of male sex hormone. In other words, the song season corresponds to the sexual cycle, a fact observed by many a naturalist with no claims to scientific training.

The results of these experiments and others not here described can be summarised in Mr. Poulsen's own words. "The experiments with the chaffinches demonstrate that the improvement of the song in early spring in adult males is due to the incipient effect of male hormone; in the juvenile birds—scarcely one year old—in addition to the incipient effect of the hormone it is also due to imitation but neither to maturation nor to practising."

Scale Model of the Thames

It is well known that scale models have been used in serious scientific research for many years; ship-models for use in tanks and aerofoils for use in wind-tunnels were probably the earliest. When appropriate precautions are taken the behaviour of the model gives an accurate prediction of the behaviour of the real object from which the model has been scaled down. In effect, the ocean-going ship or the strato-cruiser has been brought into the laboratory. A very recent development in this sort of research has been the building of scale models of rivers, complete with rising and falling tides and fine sand or powdered pumice to represent the movable material that forms riverbeds and banks and shoals (see Discovery, March 1950, and November, 1948).

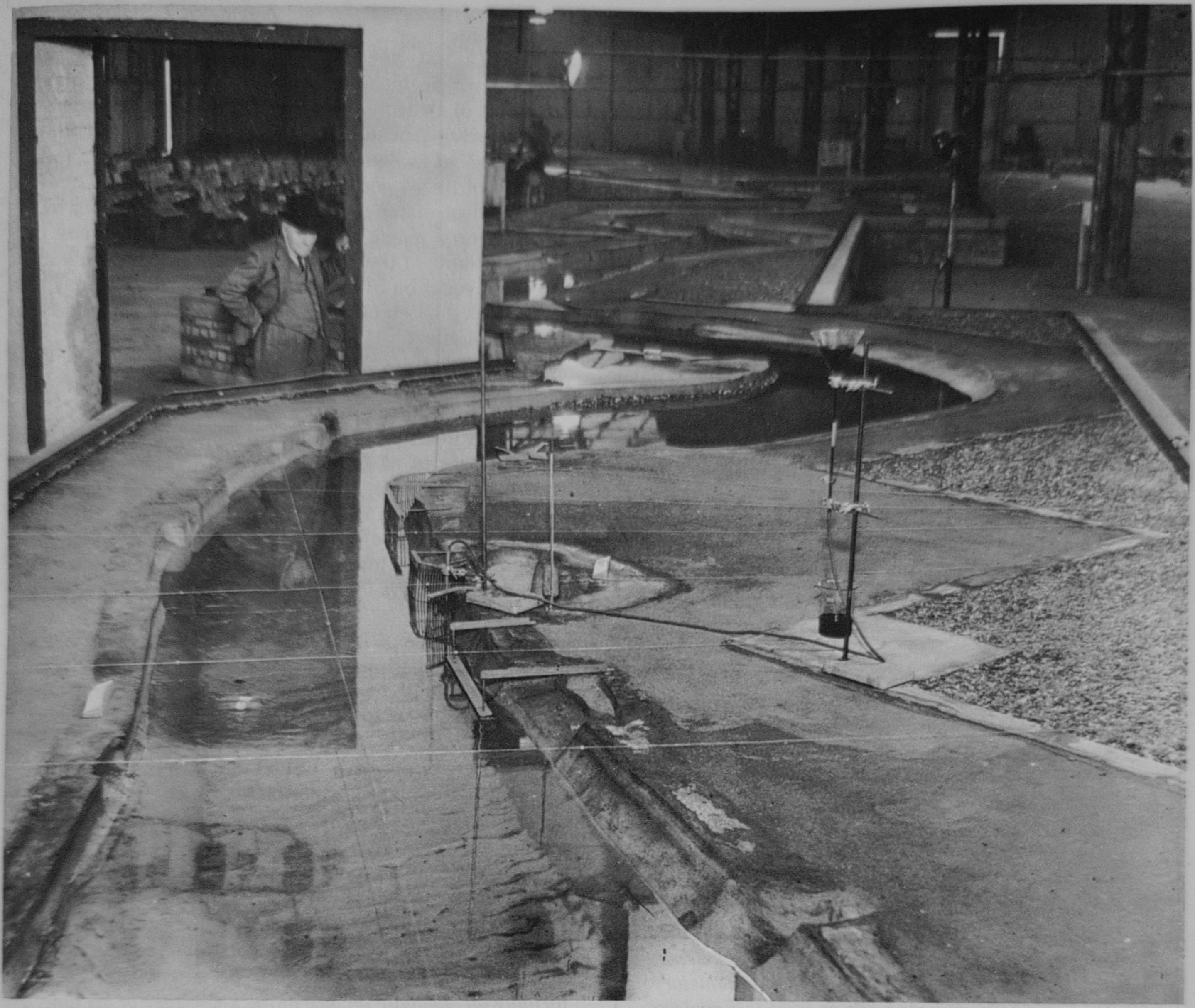
The latest of such models, built by the Port of London Authority, represents the River Thames from just east of Southend Pier to Teddington Weir, a distance of nearly 62 miles. The part from Southend to Westminster Bridge is 397·8 feet long, a linear scale of 1 in 600 or about 9 feet to the mile. Vertically the scale is bigger, 1 in 60, to give a depth of water and bank more easily examined in detail. This part of the model faithfully reproduces every bend and mudbank and channel according to the findings of the P.L.A. surveyors from 1939 to 1949. The rest of the whole stretch, that from Westminster to Teddington, is to the same scale but without any topographical similitude, being merely a convoluted channel with parallel sides. The necessary condition to justify such a labyrinth, as the hydraulics research scientists call it, is that the volume of water exchanged at the barrier between the labyrinth and the accurate model shall be the scaled-down equivalent of the water exchanged in the actual river at the corresponding barrier. (The volume of water in the labyrinth is referred to as the 'prism'.) In this way a stretch of water of no interest to the researcher, but nevertheless indispensable to the quantitative side of the research, can be accommodated in a much smaller space than the part that must be accurately depicted.

Such a model, however fascinating in its revelation of water-movement and the formation of ripple marks, and however titillating in its incidental riverside detail it might be, would remain merely a child's delight without an elaborate mechanism to provide tides and thus turn the model into an instrument of research. Tides are a periodic rise and fall in the waters of the world, the periodic time being approximately—and only approximately—twelve hours and a half. The amount of movement is not the same every day; at new and full moon the rise and the fall are greater than at other times. These periodically enhanced tides are the 'ordinary springs', the others in between being the 'neap' tides. There is also an extra effect at the equinoxes, causing abnormal spring tides. Furthermore, when the water is near land masses, and especially when in narrow channels, the above variations are still more complicated by such factors as viscous drag on the shores and the variable depths of water. The winds, too, have their effect. Most—not all—of the variations are predictable and computable so that tide tables can be prepared. It can be seen that a profile of the tidal changes with time will be a complex wave-form that varies according to the geographical position of the place for which the prediction is made. In the P.L.A. model of the Thames allowances are made for the complexity of tides by utilising the correct profile for the estuary at the seaward end. There a chamber contains water. The air-pressure above this water can be varied by means of a turbo-exhauster. Thus the water can be forced down or, so to speak, sucked up. In this way the water is drawn from, or flows into, the river. The desired tidal profile—supplied by the Liverpool Observatory and Tidal Institute—is drawn in black and white on a roll of paper so that the area between the profile and one edge of the paper is white and the rest black. The area of white is thus varying with the profile. As the paper unrolls it is scanned by light and the reflected light operates photocells. The resulting current, after amplification, is thus a faithful copy of the variation of the profile with time. The current operates the turbo-exhauster. The electronic equipment of this elaborate apparatus was designed and constructed by the Hydraulics Research Station of the D.S.I.R. The time-scale used is 1 in 77·46, or just over nine minutes and a half for a tidal period. With this scale a year's continuous tides can be initiated in less than five days on the model.

All rivers have fresh water flowing into them from the landward end—it is the cause of their existence. In a river like the Thames the volume of fresh water is so great that it affects the tidal rates and levels for some distance down river. The fresh-water discharge in the model is simulated by the pouring of water into the model at the Teddington end.

The P.L.A. model, housed in No. 8 shed at the Royal Victoria Docks and equipped with tides and fresh-water discharge, is thus ready for research, and the question arises as to what work can be done and what problems there are to be investigated. It can be said at once that the knowledge of the theory of loose-boundary hydraulics and the understanding of relationships between the model and the actual river are not yet sufficiently advanced for accurate quantitative research to be done in the way in which it might be expected on first thoughts. All the same, with skilled experimentation and the advice of experienced engineers, many problems can be examined and some very general conclusions drawn.

One of the problems is connected with the pollution of the river. This is a very serious matter, so much so that only last year another Act was added to the Statute Book about the steps to be taken by local authorities to prevent pollution. Most of the Thames pollution comes from sewage. This is aggravated by the discharge of water from power stations. This water is clean enough but it is warm—warm enough to raise the temperature of the Thames water by measurable amounts. This rise in temperature facilitates the multiplication of bacteria. When the engineer, Sir Joseph Bazalgette, built the London sewage system, the assumption was that if it was discharged on the ebb it would be carried out to sea. In actual fact the model shows, by means of an injection of dye at a point corresponding to the northern sewage outfall, that the discharge



The P.L.A. Thames model. The view is landward from just below Tilbury. On the right of the stream, near the foreground, is Tilbury basin—the docks are not shown in the model. The funnel and tubing for injecting dye below the water surface near the basin can be clearly seen. In the foreground is the Tilbury passenger landing-stage.

moves up and down with the flow and ebb for many tides before the effect of the ebb is as great as it was once thought to be. In addition, the sewage is discharged continuously, on the flood as well as on the ebb. The amount of biology and biochemistry involved in the problem is such that the P.L.A. has built a laboratory at Tilbury and provided a launch equipped with scientific personnel for work on the river itself.

The prime problem to be investigated with the model, however, is that connected with silting and dredging. Every year the P.L.A. removes 3,000,000 cubic yards of silt from the docks and river at a cost of about half a million pounds. In the model, flow patterns and the movement of bed material and the behaviour of silt can be studied. The flow pattern near Tilbury Tidal Basin can be seen with the aid of dye injected into the water at the down-river side of the basin. As the tide flows, so the dye is pushed into the basin and it does not come out. This shows that silt-bearing water is in the basin and fairly undisturbed and so the silt is deposited. It is hoped that as the investigation of this specific problem progresses it will be possible to arrive at a permanent cure for the trouble.

Another silting problem is concerned with Halfway Reach, Barking Reach and Gallions Reach, the so-called Mud Reaches. These extend some five miles down-river from the Royal group of docks. Water to maintain the level in these docks is in fact pumped from Gallions Reach, so if the problem of the excessive silting in these reaches were solved it would do something towards the solution of the silting problem in the docks themselves. It is already known that the silting in the Mud Reaches is connected with the fresh-water flow into the river and it is believed that the warm-water discharges also affect it.

The model can demonstrate successfully several phenomena of the river, phenomena known to navigators. There is, for instance, a bad whirlpool on the ebb tide off Garrison Point near Sheerness. By dusting the surface of the water in the model with aluminium powder the movement of this big eddy can be clearly shown. So can an eddy that forms off Broadness only on the flowing tide. At the seaward end of the estuary, when the tide is still ebbing in the middle of the stream, the flow has already started near the shores. Similarly, when the tide is flowing in mid-stream the ebb has started near the shores. Both these effects were easily seen with the model when floats were scattered on the surface. In fact the verisimilitude of the flow effects in the model is such that it makes one think that the very cautious expectations of the scientists may be realised more than they like to say.

HISTORY OF SCIENCE IN SCHOOLS AND UNIVERSITIES

IN the course of his presidential address to the British Society for the History of Science, Prof. Partington stressed the need to teach and study the history of science in schools and universities. He said:

Some of us may forget at times that there is in existence a deep hostility to the study of that subject. We are made aware of this in many ways. The hostility is noticeable among some teachers in schools, who dislike books which touch upon the historical aspects of their subjects. In the universities we find that the subject of the history of chemistry has disappeared from the syllabus for the degree. When this happened, we were told that the time had come when chemistry must be treated on didactic lines, that the growth and complexity of the science were such that all the energies of students were absorbed in mastering the present state of the science, and that any mention of its origins was not only a waste of time but also could only confuse and repel the student approaching the subject. Although it was seemly and useful to point out the achievements of contemporary chemists, the contributions of their predecessors, outmoded as they were, could well be treated as integral parts of a science which had now reached a stage of development not requiring any inquiry into its remote origins. This view has not been shared by all. Richard Willstätter, for example, emphasised the value of teaching chemistry on an historical basis, even going so far as to say that this method might differentiate its study in a university from that in the more hurried and less fundamental treatment suited to a technical school; but the majority seem to have little sympathy with any study of its history. I believe this attitude goes back at least to Lavoisier. In the "Traité de Chimie" (1789), *one of the great historical documents of chemistry, to which the development of the science in the first part of the nineteenth century owes so much, we find it prominent.*

The Alchemical Origins of Chemistry

THE latest issue of the *Bulletin of the British Society for the History of Science* contains the presidential address by Prof. J. R. Partington, whose record as an outstanding teacher of chemistry was briefly described in DISCOVERY (January 1952, vol. xiii, p. 30) on the occasion of his retirement. In this address he discussed "Chemistry as Rationalised Alchemy", and disposed of the misconceptions about alchemy which have been fostered by those "popular exponents of alchemy [who] never fail to adorn themselves, at least metaphorically, in a pointed cap, and would have us believe that alchemy was a branch of magic and largely a matter of hocus-pocus. In actual fact the early treatises are devoid of material of this kind, so fully known in the contemporary magic papyri. There are sometimes dramatic accounts of the finding of books concealed in altars, and the invocation of shades, and the like, but it may well be that this is based on contemporary fiction and added for the sake of effect".

Two great students of alchemy mentioned by Prof. Partington were Roger Bacon (*c.* 1214–94), T. Albertus Magnus (*c.* 1206–80), who described alchemy as the "beggardly union of genius and fire". Alchemy was turned to the service of medicine by Paracelsus (1493–1541) who taught the doctrine of the three alchemical elements—mercury, sulphur and salt. After Paracelsus came Van Helmont (1577–1644), who rejected Paracelsus's concept of the basic elements and taught that the true elements were air and water. Says Prof. Partington, "Van Helmont made the first steps towards the founding of chemistry by ridding alchemy of some of its irrational elements, by performing quantitative experiments, and by inventing the new name *gas* for air-like bodies with properties different from those of ordinary air. With Van Helmont, we are very near the true beginning of scientific chemistry." Readers will undoubtedly be aware of the fact that Van Helmont also did some most stimulating experiments which today we should consider to come within the scope of plant and animal physiology.

With regard to Francis Bacon (Lord Verulam), who lived from 1561 to 1626, Prof. Partington makes this comment: *I wish merely to say that Bacon is named as an originator of chemical methods, that he does in fact include chemistry among the sciences which must be taken into account in forming an adequate picture of the knowledge of his time, and that he recognised that in this field he was following a long tradition. He realised that chemistry could never hope to develop from a few postulates or laws, which by mathematical methods could lead to consequences which could be tested by experiment, but that it was something more complex and difficult. He recognised that the only workers who had, in his time, anything significant to say about chemistry were the chemists, or as they were then called, the alchemists, and that if progress was to be made in this field it must start with what the experts, the alchemists, had already established, and not from abstract postulates or laws taken over from entirely different fields. Chemistry, he realised, if it was to become a science, would have to be rationalised alchemy.*

Bacon had a competent knowledge of contemporary writings, including those of Paracelsus, Isaac Holland and Basil Valentine; Prof. Partington adds the comment that "The alchemical-theosophical background of much of Bacon's work was firmly grounded in contemporary England but much more prominent in Germany." Bacon, who carried out chemical experiments himself, was of the opinion that the weakness of contemporary alchemical practice arose from the fact "that the alchemist fails in 'the true proportions and scruples of practice, which makes him renew his trials infinitely and, finding that he lights upon some mean experiments and conclusions on the way, feeds upon them, magnifies them to the most, and supplies the rest in hopes', adding: 'not but that the alchemists have made a good many discoveries and presented men with useful inventions'."

Bacon believed that the development of chemical science would more probably be effected by "a diligent study of the natures of weight, colour, malleability and extension, volatility and fixedness, and of the first seeds and menstruums of minerals, than that a few grains of an elixir should in a few moments turn other metals into gold".

Bacon, according to Prof. Partington, was more sceptical about the possibility of alchemical transformation than were Boyle and Newton, "both of whom were aware that there was no proof, mathematical or otherwise, of the impossibility of transmutation". Newton did in fact apply himself most assiduously to chemistry, but "the results of his arduous labours were practically negligible". Newton lacked the knowledge of new substances, which could not be discovered by the use of such methods as had weighed the heavenly bodies and inaugurated a science of mathematical astronomy without parallel in the great achievements of all ages. Newton attempted to apply his ideas of attraction between bodies to chemistry, but without success. His ideas were developed by John Keill (who stated in 1708 *thirty* theorems of the laws of 'chemical attraction') and John Freind of Oxford, but these theoretical extensions of Newtonian mechanics were almost without influence on the progress of chemistry.

Scheele (1742–86) and Priestley (1733–1804), on the other hand, made great chemical discoveries which lay in a field amenable only to the use of the chemical method of investigation; "the main features of it were well known to the alchemists", adds Prof. Partington. "Materials of all kinds were subjected to fire, to acids, to unlikely trials; and from this series of experiments there emerged the new gases, which had been in the hands of chemists before but had not been clearly recognised. It was from this material that Lavoisier was to construct a new Science."

It is Prof. Partington's opinion that Lavoisier lacked the flexibility of mind of Priestley, and there is no doubt but that he found it difficult to revise his first ideas even after he had himself proved them to be wrong by further experiments. Prof. Partington points out that Lavoisier's quantitative method succeeded because it had many more materials to work upon than were previously available; for example, the new gases, such as oxygen, discovered by Priestley, made all the difference, and these were discovered by purely chemical methods, no use being made of any methods derived from astronomy, or physics, or mathematics. "With these discoveries Lavoisier was able, by the use of methods derived from physics and mathematics, to transform chemistry, and he was the first great physical chemist", comments Prof. Partington.

Prof. Partington's concluding words are so much to the point that it is worth quoting them verbatim:

Chemists should always be interested in the attempts of mathematicians and physicists to explain the fundamental laws of chemistry which have been arrived at by methods peculiar to the science, but if they are wise they will continue to use these laws, and feel satisfaction in them, even though they cannot be reduced to terms of concepts which seem rather foreign to the content of chemistry.

At various times we find the physical sciences dominated by particular aspects of belief, and chemistry has necessarily been influenced by these. In the period of alchemy, the notions of primary matter and substantial forms were predominant. In the seventeenth century atomism began to penetrate the science, in the eighteenth century it was hoped that the idea of universal attraction could be extended to include chemical phenomena, in the nineteenth century energy and in the twentieth the quantum theory. All these are still insufficient to cover the whole science, which goes its way to new discoveries made by its own methods.

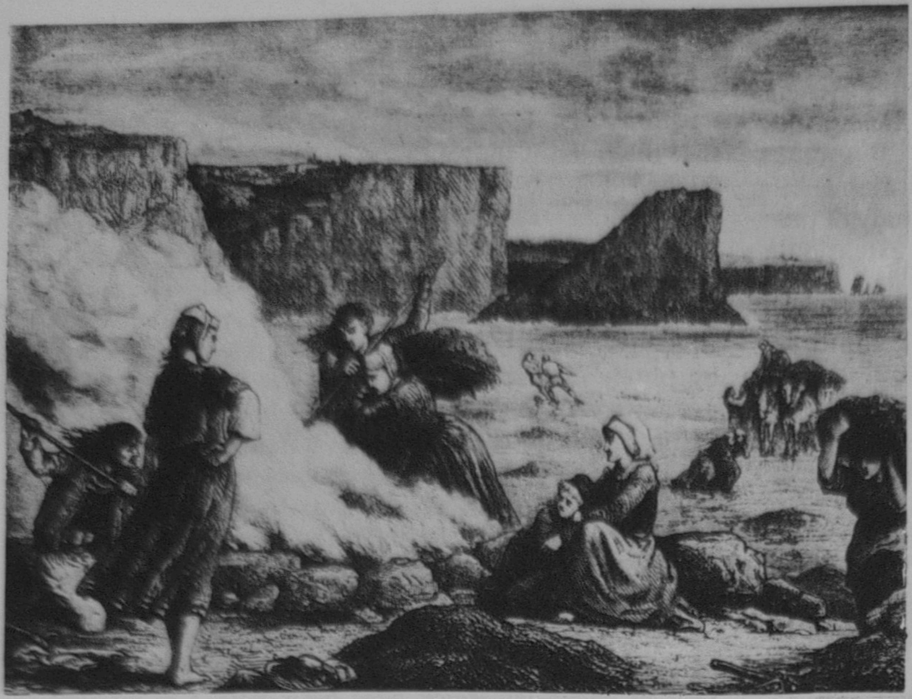
ATOMIC SURPRISE

THE first atomic bomb may have been the worst-kept secret that ever won a war, but no such criticism can be raised against the security arrangements protecting those establishments which are responsible for the design, development and production of Britain's atomic weapons. After all the talk about the slowness of British efforts to produce atomic explosives, most people were amazed when they read the following statement which was issued from No. 10 Downing Street on February 17:

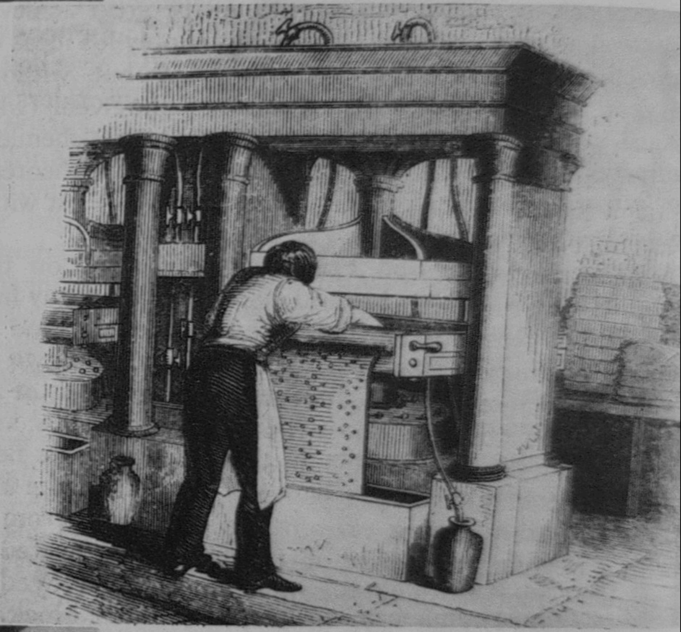
"In the course of this year, the United Kingdom Government intend to test an atomic weapon produced in the United Kingdom. In close co-operation with the Government of the Commonwealth of Australia, the test will take place at a site in Australia. It will be conducted in conditions which will ensure that there will be no danger whatever from radioactivity to the health of people or animals in the Commonwealth."

According to Chapman Pincher of the *Daily Express*, the weapon will almost certainly be a high-powered atomic bomb designed for use by aircraft and it will be detonated by an entirely new British mechanism. Explosive for the bomb will be made at the Supply Ministry factory at Sellafield, on the west Cumberland coast. Two giant furnaces for the production of plutonium, the explosive in the Nagasaki and Bikini bombs, have been working there more than a year. The new British weapon is believed to be more efficient, though not necessarily more powerful, than any U.S. weapon, added Mr. Pincher.

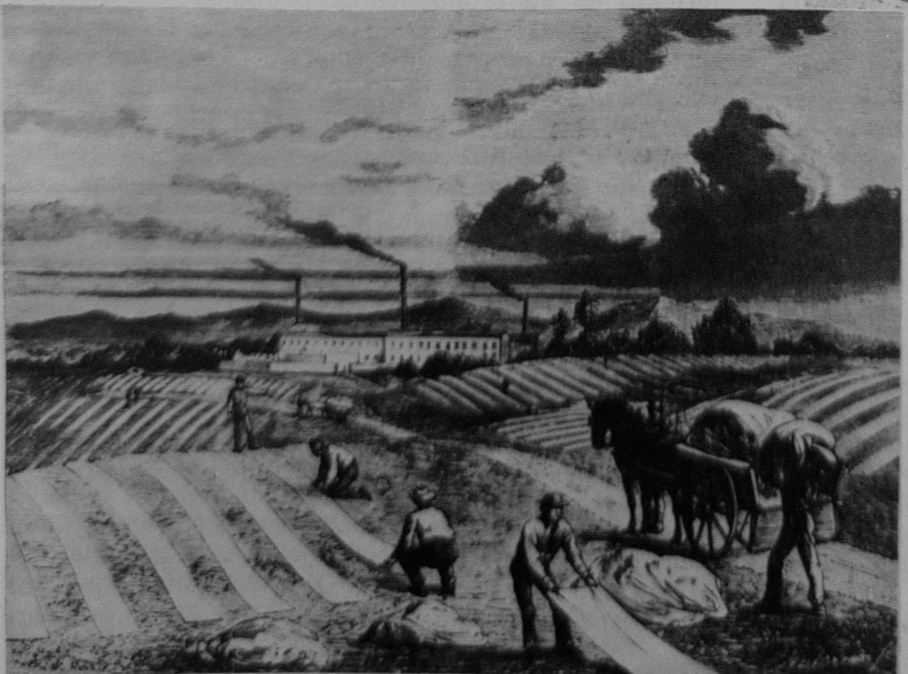
When people recovered from the shock of the bald statement from Downing Street, they began to speculate about a variety of things. Where exactly would the impending atomic weapon tests be held, they asked each other, and nearly everyone who thought he was 'in the know' jumped to the conclusion that the test was bound to be made on the Woomera rocket range. But this became a doubtful proposition when the Prime Minister of Australia stated categorically that he had not even been informed that a test would be made in his country. Then came a statement that the testing site would be somewhere near Christmas Island, which is in the Indian Ocean south of Java. At this stage most people stopped guessing and contented themselves with the reassuring thought that Britain and America between them should soon be able to muster sufficient atomic armament to deter any would-be aggressor who is planning to use atomic bombs.



Before the Chemical Revolution soda had to be supplied from natural sources: wood-ash, seaweed (kelp), etc. Here seaweed is shown being burnt for the production of kelp on the coast of Brittany, a process which was also exploited extensively in Scotland.



A chemical contribution to fashion: a Bandana press at Messrs. Monteiths, Glasgow. The press was introduced about 1802, whereby bleach liquor was forced through perforated metal stencils which gripped the dyed cloth, thus discharging patterns; this technique made it possible to reproduce many simple designs such as that of the well-known Bandana handkerchief.



To Perth, cloth from all over Britain came to be bleached. This print, probably of one of those early Perth bleach fields, illustrates the competition between industry and agriculture for the use of land characteristic of that period. The return of the land to agriculture as the result of the introduction of chemical bleaching was heralded as one of the great triumphs of the Chemical Revolution.

The Chemical Revolution

F. E. WARNER, B.Sc., M.I.Chem.E.

HISTORY is, without doubt, too serious a matter to leave to the historians. The grand perspective betrays them into epigram, from "History repeats itself" or "History repeats itself; first as tragedy, the second time as farce" according to Marx, to the opposite extreme "The only thing we learn from history is that we learn nothing from history." The teaching of history in schools often does no more than repel the student of science from further study, once the indispensable minimum for the School Certificate has been taken in. He retires from the struggle with political and dynastic questions to side with Henry Ford, who gave the engineer's conclusion that "History is bunk."

Over the last twenty-five years, a great deal has been happening in the teaching of history to change all this. One of the agents was the Piers Plowman series of social and economic histories. My old master, the late R. H. Snape, who wrote one of the best of these, took his example from Lord Acton: "The great historian must now take his meals in the kitchen." The study of household accounts, rent rolls and wage packets has brought history home, and with it the student. In no other way can we be given a sight of the continuity and contingency of events.

There remains a gap. The study of the useful arts and manufactures is almost confined to the purely mechanical. The Industrial Revolution is an affair of the steam-engine, the spinning jenny and the mechanical loom. This basis has now been challenged by Dr. and Mrs. Clow in their new book.* They show that the mechanisms whose effects can be assessed by the economic historian were accompanied by developments in chemical technique which can only be understood by the trained scientist and one who is familiar with the changes in names of even common materials since the period they discuss. Yet the ordinary scientist would be quite incapable of employing the research methods of the historians which come naturally to these authors. They have struck from a hidden vein a spark which shows up not only a revolution in chemistry but in scientific thought itself.

The period chosen for detailed examination is 1750–1830 and the place Scotland. The choices are deliberate and convincing. The period is, in Mumford's phraseology, the palaeotechnic: that is a basis of coal and iron, as distinct from the eotechnic of water and wood and the neotechnic of electricity and alloy. Scotland is the place of choice because of the first-hand material such as John Sinclair's *Statistical Account of Scotland* (1791–9) and the *New Statistical Account* (1845) which it inspired. It also produced the leading school of chemistry in Britain, which was active and applied, in contrast to the moribund universities of England. The period begins with the first sulphuric acid works in Scotland at Prestonpans in 1749 and ends with the use of heated air for blast-furnaces by Neilson in 1828. The rise of manufacture up to the starting date is obscured in ordinary historical studies by the overwhelming political effect of the crushing of the Jacobite risings of '15 and '45. The main chemical industries were, however, developed and changed from dependence on wood to coal. This applied to salt, gunpowder, alum, sugar, fermentation, glass and pottery. Iron-making scarcely felt the change until 1760 when the use of coal reached Scotland at the same time as at Coalbrookdale in Shropshire, and a long time after its use by Abraham Darby in 1709.

For the present study, a mass of data has been assembled for analysis and interpretation under the following heads:

(*a*) primary chemical substances such as salt, potash, etc.;
(*b*) the problem of the synthesis of soda;
(*c*) the first substance to be manufactured on a large scale, sulphuric acid, and an offshoot of its availability, aeronautics;
(*d*) the textile complex—bleaching, dyeing, calico-printing, mordant production, waterproofing, paper;
(*e*) furnace products—glass and pottery;
(*f*) metals—iron and lead;
(*g*) coal as a chemical raw material—the gas and tar industries, matches;
(*h*) agriculture and industries based on its products, sugar, brewing and distilling, food preservation.

The Role of Salt

The history of salt has already been discussed in this journal (DISCOVERY, Nov. 1951, p. 360 and Dec. 1951, p. 387) and particularly the effects of fiscal changes on centres of production. Initially the Tyne was the main centre of production, controlling much of London's supply. When Cromwell repealed duties on the importation of Scottish salt into England (1654) many pans at Shields were given up owing to Scottish competition which was stimulated. Later in the century the discovery of rock-salt in Cheshire further undermined the industry on the Tyne and contributed to the rise of Liverpool as a port. It also hit Scottish industry based on sea-water, as one ton of saturated brine from rock-salt gave as much salt as eight tons of sea-water.

The works on the Tyne had been established when coal was substituted for wood as a fuel for brine evaporation and iron for lead as a construction material for the pans. The availability of coal on the Forth was the basis of Scottish industry. By 1765, the colliery and salt works at Bo'ness were reported to be "very great". They were operated by Dr. John Roebuck, founder of the vitriol works at Prestonpans and partner in the Carron Iron Works, which made salt pans of iron. The Bo'ness pan was 55 feet by 32 feet and consumed 10,000 tons of coal per annum. Such a pan required the outlay of £300 in capital and cost £30 to £40 every two or three years to maintain it in working order. Conditions of labour had not advanced as far as the technique. Prior to an Act of 1735, the wages of Scottish salters were paid in salt and the

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*This book, entitled *The Chemical Revolution*, is due to be published on April 15 by Batchworth Press, London, at 50*s*. The manuscript of this work gained the Senior Hume Brown Prize of Edinburgh University, and a thesis written by Dr. Clow and based on the conclusions contained in the final chapter of the book gained him the Blackwell Prize awarded by Aberdeen University.

Act (1775) 15 Geo. III, c. 38 opens, "Whereas many colliers, coal bearers and salters in Scotland are in a state of slavery or bondage, bound to the collieries and saltworks where they work for life, and are sold with the mines. . . ."

By the end of the eighteenth century, the pressure of industries using salt brought about the repeal of taxes. The use of salt glazes for pottery, of bleaches based on chlorine and the synthesis of soda, all demanded a cheaper raw material. The impact was immediately felt in the kelp industry. This was the native Scottish production of potash which competed with imported barilla on which tax had to be paid, and has been treated in *The Heavy Chemical Industry in Widnes* (see DISCOVERY, Oct. 1951, p. 305).

Kelp and Synthetic Soda

The gathering and burning of seaweed became competitive in cost as forests were progressively denuded and could no longer be burnt just for ash. It grew increasingly important until it became the dominant occupation in the Highlands and Islands. It led to a growth of population unaccompanied by any increase in the productivity of the soil. The landlords made huge profits, Lord Macdonald for example taking an average income from kelp of £20,000 a year. It was exported to England for the manufacture of glass, soap and alum. Variations in the quality of kelp were wide and adulteration was common. This led to a demand for methods of analysis, and one of the first recorded uses of volumetric analysis is due to Charles Tennant who estimated barilla with a solution of sulphuric acid, using an extract of radishes as an indicator (1817). By this time, the knell of kelp had been sounded. A reporter from South Uist wrote in the *New Statistical Account* ". . . because of the removing of the duty on salt and sulphur, the income of these islands is reduced from £15,000 to £5000 per annum, and the manufacture of kelp is only continued to pay the rents". The cause of the decline is here laid at the door of the raw materials for synthetic soda. The sequel was the emigration of the population to America. A small revival, for the sake of potash and iodine, took place in the 1914–18 war, and today the gathering of seaweed for the production of alginates gives hope of restoring some industry.

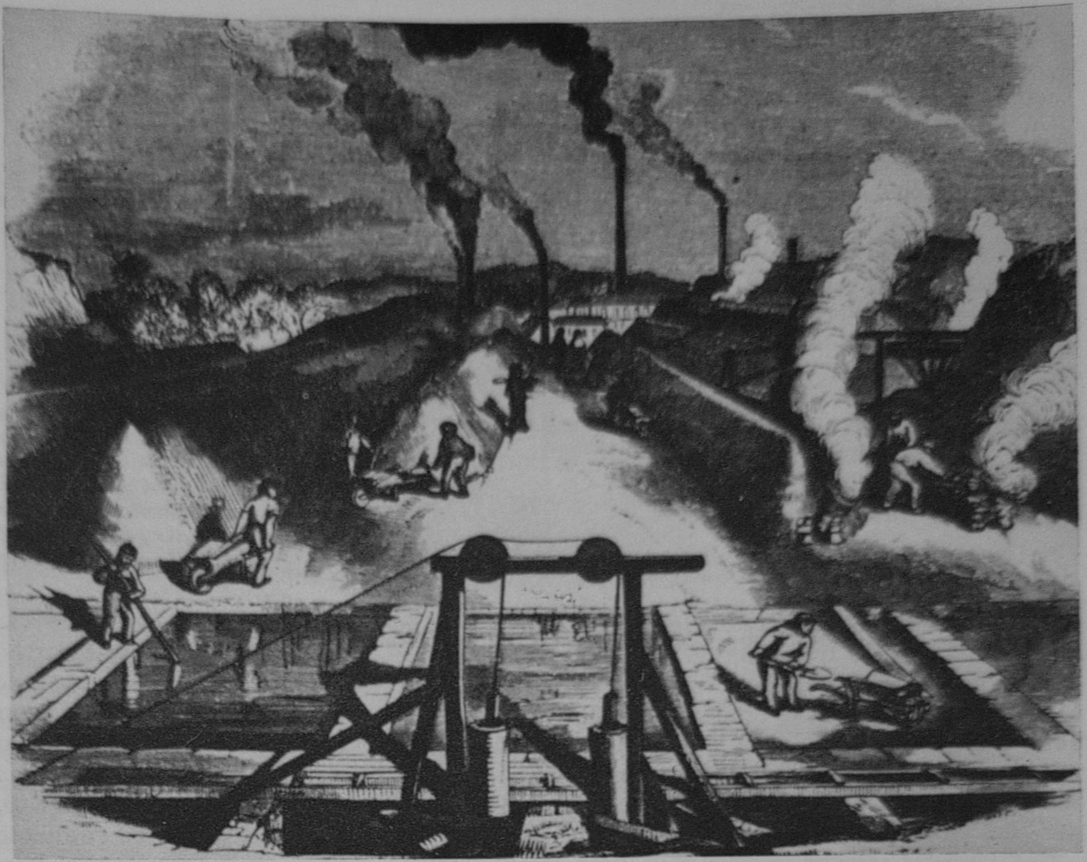
The effect of the synthetic alkali industry in fostering the whole chemical revolution was summarised by Stephen Miall in his *History of British Chemical Industry*:

"The works of an alkali manufacturer tended to become larger and more complicated: he began to make soda, using common salt and sulphuric acid and other raw materials. After a time he started to make his own sulphuric acid by burning sulphur or pyrites; if he used pyrites, it was probably a mixed sulphide of copper and iron, and it was comparatively easy to make copper sulphate and ferrous sulphate from the roasted pyrites. The process of making sodium sulphate produced large quantities of hydrochloric acid and, as nitric acid was required in the manufacture of sulphuric acid, the alkali manufacturer easily developed into a manufacturer of hydrochloric, nitric and sulphuric acids, and various salts of sodium, copper and iron. It was a very common development for the alkali manufacturer to use the chlorine he rediscovered so as to make bleaching-powder, and in these ways he became a maker of calcium chloride and bleaching powder and, as demands for them grew, he made other salts of sodium and calcium required in large quantities. The manufacture of all these 'heavy' chemicals became in this way an involved process, in which one part was dependent on the others and almost every effort to prevent waste involved the manufacture of some new product."

Dr. and Mrs. Clow bring out the preponderating influence in this development exercised by Scotland. On the one hand was Roebuck, an immigrant to Scotland from Birmingham, working with Black and Watt. On the other hand was the ninth Earl of Dundonald, in association with Lord Dundas and various manufacturers on the Tyne. Roebuck with Garbett set up the first chamber plant for sulphuric acid at Birmingham in 1746. They followed it with a plant in Prestonpans three years later, and Roebuck then began to be interested in synthetic soda. Through Black, Professor of Chemistry at Edinburgh, he was put in touch with James Watt who was working on the problem of a separate condenser for Newcomen's engine. This was directly inspired by Black's work on latent heat, and the first work Watt undertook for Roebuck was on alkali production, arising out of Black's work on the alkaline earths and carbon dioxide. Roebuck had also started the Carron Iron Works and extended his interests to coalmining so that the construction of engines for water pumping directly concerned him. He did, in fact, pay off Watt's debts to Black and financed a patent on Watt's engine in return for a two-thirds share in the invention. He was to lose control of the patent to Matthew Boulton, when he later got into financial trouble. There is no evidence that Watt and Roebuck brought their soda process, by decomposition of sea-salt with lime, to commercial production. Another Scotsman, James Keir, who had settled in Birmingham, appears to have produced the first workable process around 1770, and in 1780 produced caustic soda direct by the passage of a solution of sodium sulphate through a sludge of lime.

The other line, through the Earl of Dundonald, led to the production of alkali at Walker-on-Tyne. He had found William Losh experimenting on alkali there and sent him to Paris in 1791 to study chemistry. The year was the one which saw Leblanc awarded a prize for his process. The Newcastle man evidently learnt enough chemistry to enable a successful alkali works to be set up with Lord Dundonald as a partner in 1796. Through the influence of Lord Dundonald in the Government, an Order in Council was made allowing salt to be used free of duty for soda manufacture at Walker, provided it was denatured with soot and an excise-man lived on the premises. A general encouragement to other manufacturers to set up was not given until the repeal of the salt duty in 1823, and the development of Widnes followed.

The growth of the alkali industry came from the demand for increasing quantities of soap in the rapidly developing textile industries. These also required bleaching agents and a direct demand arose for sulphuric acid as a bleach to replace sour milk and bleaching fields. Tennant had erected a chamber plant at St. Rollox in Glasgow in 1804 and was already the possessor of patents for making liquid bleach from chlorine, and for bleaching powder. The first process had probably been gleaned as an idea from



The alum works at Hurlet, which in its time was the largest alum plant in Britain. The manufacture of alum, which was required by the dyeing industry for use as a mordant, began in Scotland towards the end of the eighteenth century.

an ex-employee of French manufacturers of eau de Javelle, a hypochlorite solution, but the second is undoubtedly the work of Charles Macintosh, whose name provided a household word for raincoats. The St. Rollox works rapidly expanded to become one of the largest chemical works in Europe, and by 1830 it covered ten acres.

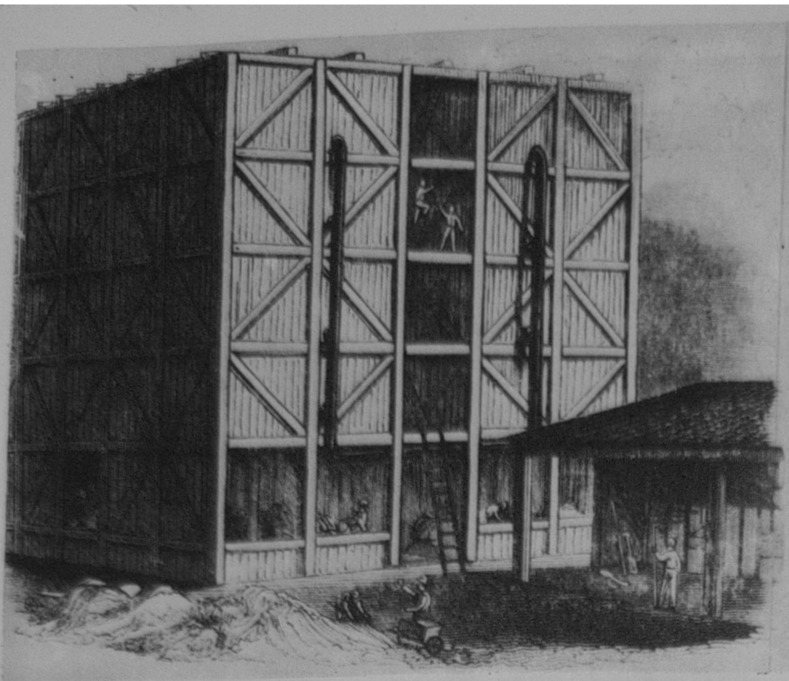
After bleaching, the colouring of textiles fostered new developments in chemicals. A great deal of legislation attempted to control imported printed textiles, but the coloured materials produced at home were for long inferior in quality. To replace indigo, Prussian blue was made and Charles Macintosh started making this at Campsie, Stirlingshire. In 1771 a new works was set up by his father near Glasgow to manufacture cudbear. This was a purple dye obtained by macerating and digesting lichens with ammonia. The ammonia was obtained from the chamber-pots of Glasgow, 2000 gallons of urine daily being collected by men with carts and pocket hydrometers, to detect adulteration, made by an instrument-maker named Twaddle.

The actual processes of dyeing on a large scale were put on a scientific basis by Benjamin Gott who used steam for heating dye-baths and employed every method of physical control.

The fundamental changes were, however, to come after the period considered, with the discovery of coal-tar dyes by Perkin in 1856. Apart from dyeing, a big development in calico printing took place, once the use of chlorine agents for bleaching the calico had been established. The fixing of the dyes was carried out by mordants, of which alum was the chief and formed one of the products of the Macintosh works. For many of their products, ammonia was a raw material and in 1819 Macintosh contracted with the newly established Glasgow Gas Works to take all their by-products for the sake of the ammonia content. By distillation of the tar, he separated a fraction called naphtha which he recognised as a solvent for rubber. Turpentine and ether had been used for this purpose and the possibility of waterproofing articles had been suggested. In 1822 he obtained a patent for cementing together two thicknesses of cloth with a solution of rubber in naphtha, thus rendering the textile impervious to water. So started the famous firm which began production first in Glasgow, and later extended its activities in Manchester.

Throughout the development in the period studied of other industries such as glass, pottery and iron the names of Roebuck and Boulton crop up again and again, with contributions based on chemical discoveries of the nature of the processes involved. They also realised the effect of heating air for the blast-furnaces. The physical basis for much of the advance had been provided by the formulation of the 'gas laws' by Charles and Gay-Lussac. These had been developed for the purpose of studying the performance of balloons, which had been given a boost by the production of hydrogen from iron which was practicable as soon as cheaper supplies of sulphuric acid became available.

The use of coke brings the story back to Lord Dundonald. First-class material is presented for the first time as a result of the Clows' researches into documents in the National Library of Scotland dealing with Dundonald's activities. To retrieve the family fortunes, he engaged in a variety of manufactures, alkali having already been mentioned. By 1781 he had investigated coal-tar manufacture with a view to making material for protecting ships' bottoms and obtained his patent for ". . . the sole Power, Privilege, and Authority, of making, using, exercising, and



The Lead Chamber Process, circa 1840. This picture is the oldest known print of a British lead chamber plant. At that time there were in the country about a hundred similar small units making sulphuric acid.

vending, within His Majesty's Kingdom of Great Britain and Dominions, his Invention of a Method of Extracting or making Tar, Pitch, Essential Oils, Volatile Alkali, Mineral Acids, Salts, and Cinders, from Pit Coal, for the Term of Fourteen Years". By 1782 experimental tar works were erected at the family estate of Culross Abbey. The actual works put up at Upper Cranston, near Dalkeith, were described in the *Statistical Account*:

"At Upper Cranston, works have been lately erected for extracting tar from pitcoal: an ingenious process, which reflects much honour on the Earl of Dundonald, who made the discovery, and enjoys by patent an exclusive privilege for the manufacture.

"The coals are put into ovens, and after being kindled, are slowly decomposed: while the volatile parts fly off into separate reservoirs, where they are condensed. Each condenser has two ovens appropriated to it, and between the ovens and condensers is placed a long leaden cistern filled with water, in order to hasten the process. The condensed fluid is then conveyed from the condensers, by a cock into wooden pipes, which lead it into a pit from whence it is pumped into the still. By the act of distillation, or boiling, the steam flies off into another large wooden vessel, where it is condensed into an oil and volatile spirit. The distillation continues for the space of four and a half days, when the residuum in the still makes excellent tar. The oil and spirit are then drawn off into a smaller vessel, and as the oil swims on the top, a separation is easily made, by drawing off the spirit. If the tar is boiled in the still for five and a half days, the stuff remaining in the still is then called half-pitch; and should the process be continued a day longer, it would become as brittle as glass. The volatile spirit is distilled a second time before it is exposed for sale, and afterwards made into hartshorn by the chymist."

The vicissitudes of the works make a fascinating story. An extension of the patent was obtained and tar works set up near iron works which could take up the coke. Although they prospered for many years, the refusal of the Admiralty to make use of coal tar for preserving ships' bottoms cut away the foundation of the business. Dundonald came very near to developing coal-gas, and he communicated his discovery of its lighting properties to James Watt, at whose Birmingham firm Murdoch made the first successful installation. Like Roebuck, he failed to profit from his discoveries. This was partly because he was unsystematic, but in many ways he was too far in advance of his time. He was reputed to be very good-hearted and was one of the first coal owners to cease using female labour for carrying coal.

If other industries have to be passed over, no account of Scotland would be complete without reference to distillation. Its importance has been underestimated by economic historians, particularly when it is realised that one Scottish distillery contributed to the Exchequer a sum of money equivalent to the whole land tax of Scotland. The various bases of taxation, on malt, on the alcohol content, on grain and on sugar, were a perpetual challenge to national ingenuity. It is gratifying to learn that in Edinburgh in 1777 there were eight licensed stills and 400 unlicensed! Owing to the tax on malt, the best whisky was made illegally since only malt was used and slow distillation. The Act of 1788 basing the duty on the size of the still led to a great speed-up in distillation rates by modifying the design, an improvement carried out by an Englishman. The influence of the national sport of beating the taxes on technological development is well illustrated here and would repay further study. It has been given topicality by the contribution of Geoffrey Bing, M.P., to the recent Parliamentary discussion on the Customs and Taxes Consolidating Bill. He pointed out that breweries are allowed 6% loss in processing before duty is charged, whereas modern breweries can keep down to about ½%. The high figure was fixed in the old days of primitive bottling plants, wooden vats and a much lower tax. The high tax of the present day makes it worth while to pay for the utmost refinements in plant to avoid losses and Mr. Bing reckons the gift from the Treasury to the brewers amounts to £12,000,000 a year.

With commendable patriotism, the Clows complete their book with a study of the personages who made up Scottish scientific and industrial society during this period. It goes a long way to explaining the drive which resulted from the interaction of the theoretical and practical in a suitable milieu, as it did with the Royal Society in London a century before and the Lunar Society in Birmingham contemporaneously.

Questions of Weather Control touch the lives of all of us; yet of every hundred men and women thus personally affected, only about two people are keen to learn about the *modus operandi*. The remaining ninety-eight simply want to know where Weather Control could 'land' us.

Control of the Weather

RICHARD BLAIR

Twentieth-century scientists are not yet able to imitate the celestial mechanics employed by the court magicians of the great Kubla Khan, who were reputedly always able to ensure perfect weather for each and every exploit of their all-powerful prince. Nor may present-day climatologists hope to find the secret behind the magic wielded by the Danish witches who were burnt at the stake for bringing about those violent storms which prevented Princess Anne from sailing to Scotland to join her royal spouse, King James VI. Today's men of science are more limited in their aim; they confine themselves to the more prosaic methods of patient investigation, never-ending study and experiment, and watchful care. At the same time, the mere layman is apt to regard the result of the past five years' intensive research into Weather Control as magic of a very high order; for Canadian, Australian and American experts are now in a position to satisfy customers who require heavy natural showers at short notice (though the showers frequently fall in unwanted places), as well as to obey instructions to divert unwanted rainfall from territories in need of drier conditions.

Weather Control and Food

Nevertheless, today's dexterous manipulation of the earth's rainfall brings us merely to the outermost fringes of the full problems of Weather Control. One engineer, Sir Claude Gibb, C.B.E., F.R.S., envisages the large-scale utilisation of electricity for pump-produced rain as a means of combating in some degree our ever-increasing shortages of foodstuffs. At the present time about six to eight acres of cultivable land per head of the world's population are available for the production of food and other raw materials. With present yields and agricultural techniques, this area barely suffices. Higher levels of production must therefore be attained, and some think that the achievement of this objective will necessarily mean more and more interference with the mosaic of Nature. At this point the climatologist chips in with his assurance that rainfall manipulation will not interfere with Nature's cycle, for rain-making may proceed only from naturally formed clouds already in existence. Present-day techniques would therefore appear to be incapable of increasing or diminishing the general level of rainfall from the skies. Local changes in time and place may, however, be effected. In other words, it may prove possible, at will, to increase the rainfall of selected areas at the expense of those adjacent, and vice versa.

Shortages of Water

As to those arid regions in which the non-arrival of rain may mean famine, pestilence and death, Unesco is organising, in conjunction with the Research Council of Israel, a seven-day International Symposium on problems of desert research in Jerusalem, next month.

Later this year the Institute of Biology will hold a three-day conference at the Royal Institution in London, on the "Biology and Productivity of Deserts, Hot and Cold", at which distinguished lecturers from eight countries will speak.

Among territories suffering from deficient rainfall, northern Australia looms large. Owing to inadequate rainfall during last year, this immense territory is threatened with a loss of 40% of the breeding cattle and 80% of the new-born calves. Several of the western states of America, too, have long been short of water for agricultural purposes.* Schemes to supplement water supplies, especially in California, are already in operation, and more than 200 million acres in the United States are reported to be scheduled for rain-making projects.

In Britain lack of water is not so serious a difficulty. It is surprising, however, that during 1951, a year of excessive rainfall, several parts of southern England did not receive their average quota of rain. Over a considerable area of the south of the country experts consider that the crops could use from four to six inches more water than usually falls as rain, and it has long been necessary to utilise river water to supplement local rainfall, well-water, etc. Year by year, water continues to be run off into the sea far more rapidly than it can be collected on land.

Rainfall and Fertility

Although heavier rains may in some instances help to increase the world's stocks of foodstuffs, there are other cases in which arid conditions are imperatively necessary to the same beneficent end. Guano, for example, has played an important role in the feeding of men, women and children. For more than a generation, starting with the 'hungry forties' of the nineteenth century, guano constituted a substantial proportion of Britain's fertilisers. The preservation of this product is only tolerably complete on rainless sites. Even quite moderate or infrequent moistening leads to the breakdown of nitrogen compounds into volatile substances. It might prove possible to divert rain from the guano sites by artificial means.

In the comparatively near future, Weather Control may begin to play an important part in the reduction of wing-borne, soil-borne and water-borne plant and animal

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* The dangerous aridity of Australia was brought home with tragic force by the recent bush fires in northern Victoria and New South Wales (January 1952) which burned out some 500,000 acres of grazing land, quite apart from the hundreds of square miles of agricultural land which were devastated in other parts of Australia.—EDITOR.

For centuries man has sought ways of controlling the weather, but without much success until the Americans succeeded, soon after 1945, in producing artificial rain by bombing rain clouds with 'dry ice'; soon afterwards it was found that silver iodide was as effective for this purpose as 'dry ice'. This picture shows South African scientists experimenting with a small rain-producing unit which works by generating a cloud of silver iodide. The U.S. Nobel prize-winner Irving Langmuir has estimated that only 200 lb. of silver iodide, distributed strategically, is needed to deposit all the moisture contained in the earth's atmosphere. In America, which pioneered this technique of rain production, this method of Weather Control has fallen into general disfavour because it has proved to be so uncontrollable.

diseases. The balance of the argument is decidedly in favour of diminished rainfall, in the majority of territories involved. The most familiar instance is that of the mosquitoes and flies which spread malaria, pests which, of course, flourish exuberantly in regions of plentiful rains, floods and swamps. The as yet unrivalled English dessert apple needs fairly dry areas if it is to avoid fungal diseases, for the latter seem to be more easily controlled where heavier rains do not prevail. Witness, also, the incidence of turnip 'dry-rot', the graph of which goes up with a rapid sweep in seasons of heavy rainfall, this canker being caused by a very tiny, insignificant-looking fungus which thrives especially well in cool, moist weather. Conversely, high humidity is unfavourable to the development of certain aphids responsible for the dissemination of sugar beet curly-top virus. Weather Control becomes all the more interesting to the farmer when it is remembered that insects provide the commonest means for the diffusion of plant viruses.

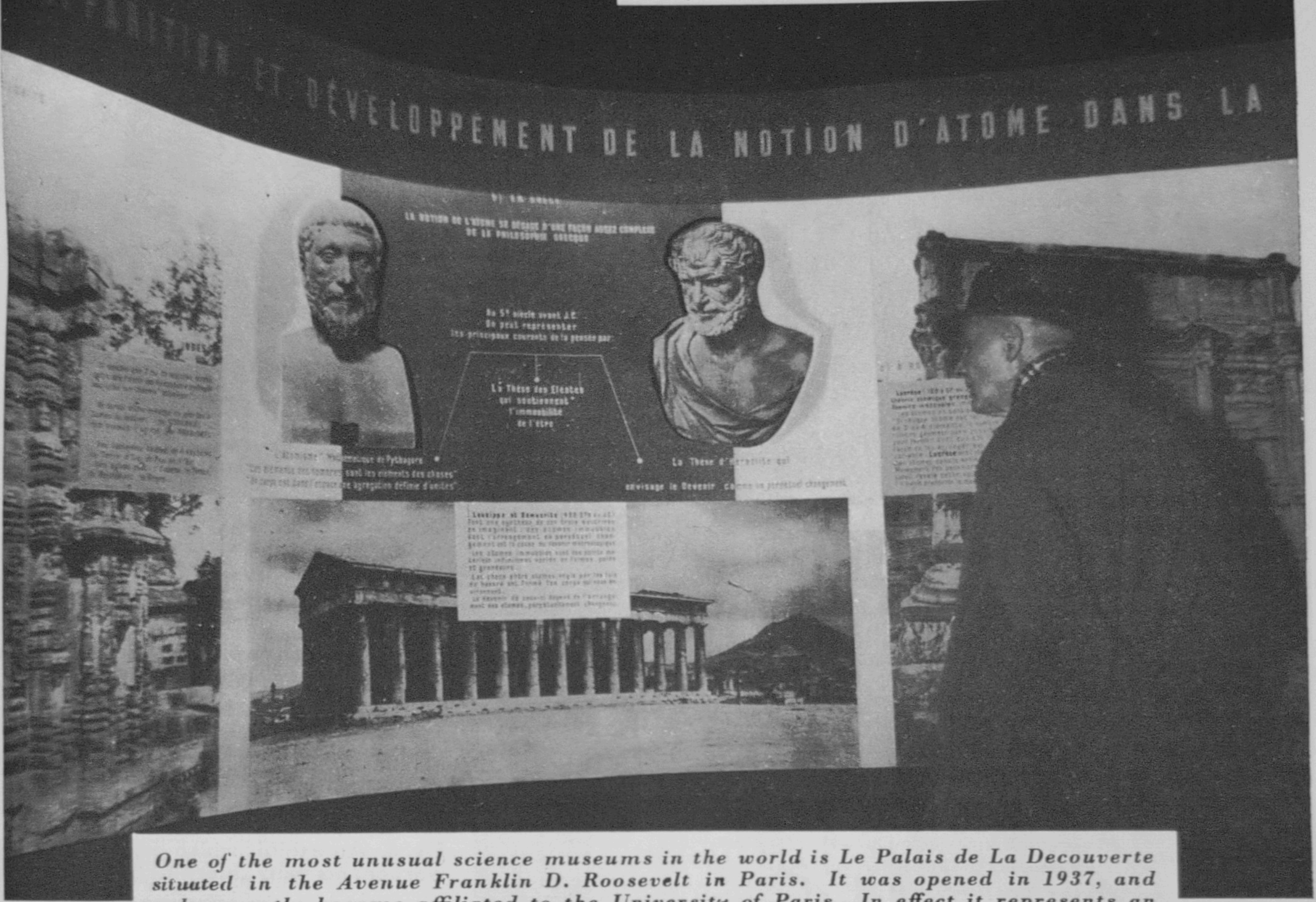
Redundant Rainfall

Any discussion of damp climates inevitably arouses thoughts of the straits to which several parts of Scotland have been reduced. Efficient Weather Control might halt the long-continued drain of Scottish emigration. With less rainy seasons in spring, summer and autumn, Scotia's magnificent scenery and warmth of hospitality could provide a cure for many of her economic and social difficulties. Numerous overseas visitors would infinitely prefer Scotland for a prolonged holiday were it not for the prevalence of Scots mists and rains. Science is now able to cause rainclouds to discharge their burden over selected districts, in favour of drier conditions in scenic beauty spots. No patriotic Scot would feel called upon to write a letter of complaint to *The Times* should a few of his everlasting drizzles be decanted into the ocean or into one of the spacious locks or reservoirs now being utilised for the new and highly serviceable generating stations of Scotland!

(The first substantial note in DISCOVERY *about artificial rain appeared in June 1948: the July 1951 issue contained an article on "Artificial Rain in South Africa".)*

The Palace of Discovery

These photographs by Paul Almasy show typical exhibits in this museum.



One of the most unusual science museums in the world is Le Palais de La Decouverte situated in the Avenue Franklin D. Roosevelt in Paris. It was opened in 1937, and subsequently became affiliated to the University of Paris. In effect it represents an ambitious piece of popularisation. I quote the words of its director, Andre Leveille: "There have been many science museums, but their nature has been static; their whole design stands in contrast to that of the Palace of Discovery. No other body has ever set itself the task of existing in a constant state of evolution, so that it may be able to demonstrate, as vividly as possible, the changing aspects of the day-by-day progress of scientific research. This is the aim of the Palace of Discovery. The enormous scope of its activities has served to popularise science, to make the Palace a link between the laboratories and the general public. It is an institute of advanced scientific training, yet which is open to everybody; it is a new weapon forged in the service of scientific discovery."

(Discovery, February 1946.)

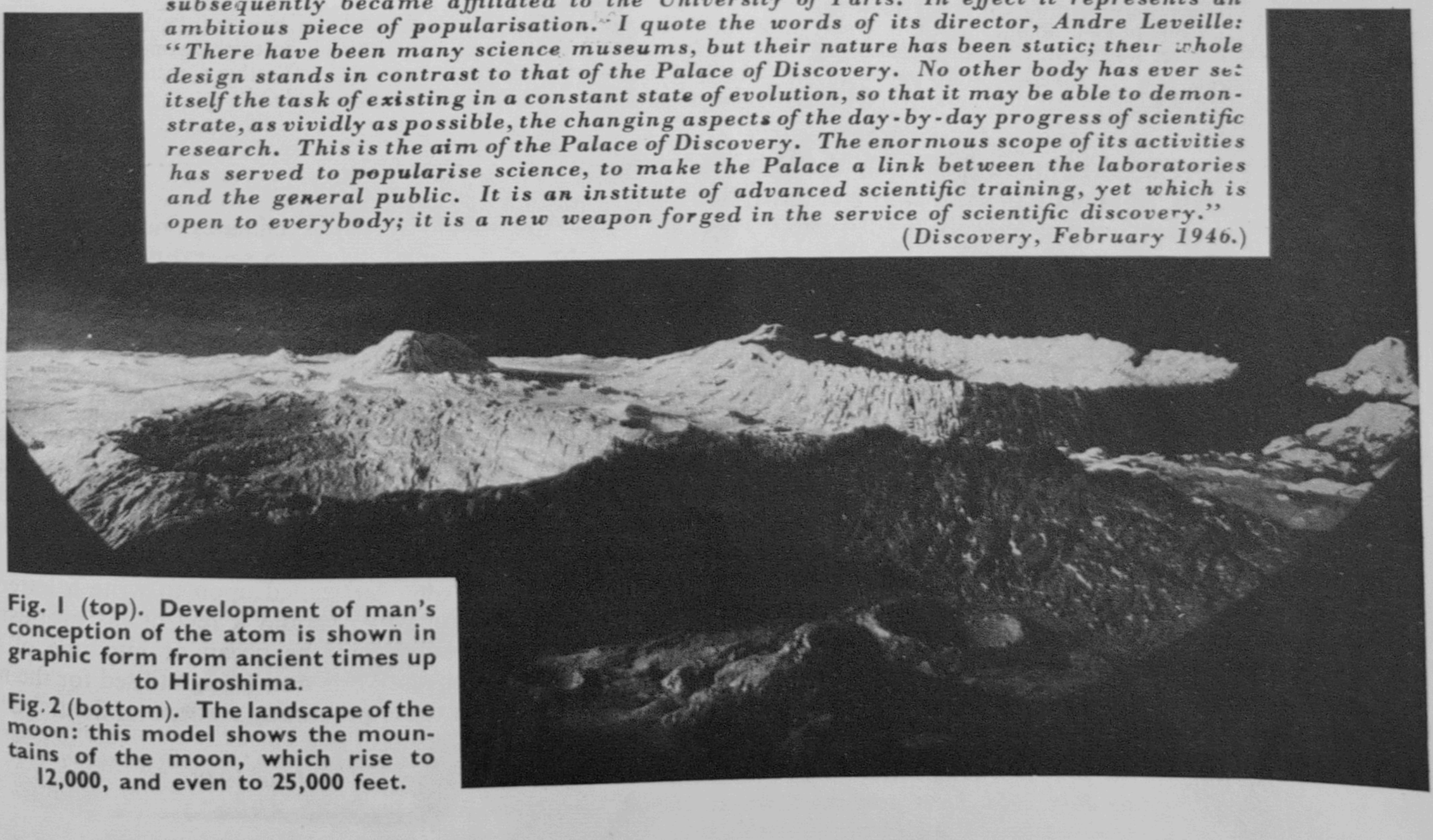
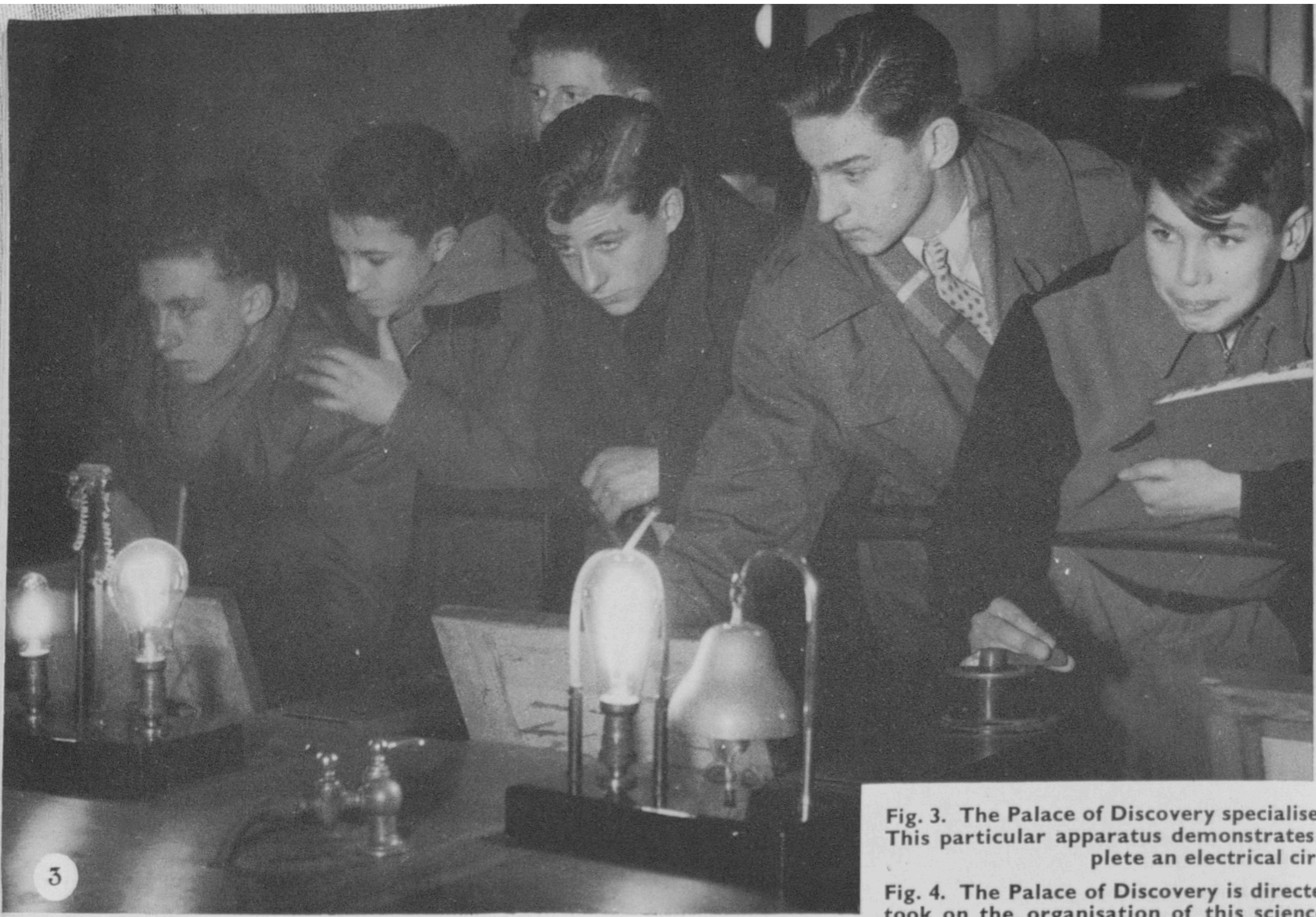


Fig. 1 (top). Development of man's conception of the atom is shown in graphic form from ancient times up to Hiroshima.

Fig. 2 (bottom). The landscape of the moon: this model shows the mountains of the moon, which rise to 12,000, and even to 25,000 feet.



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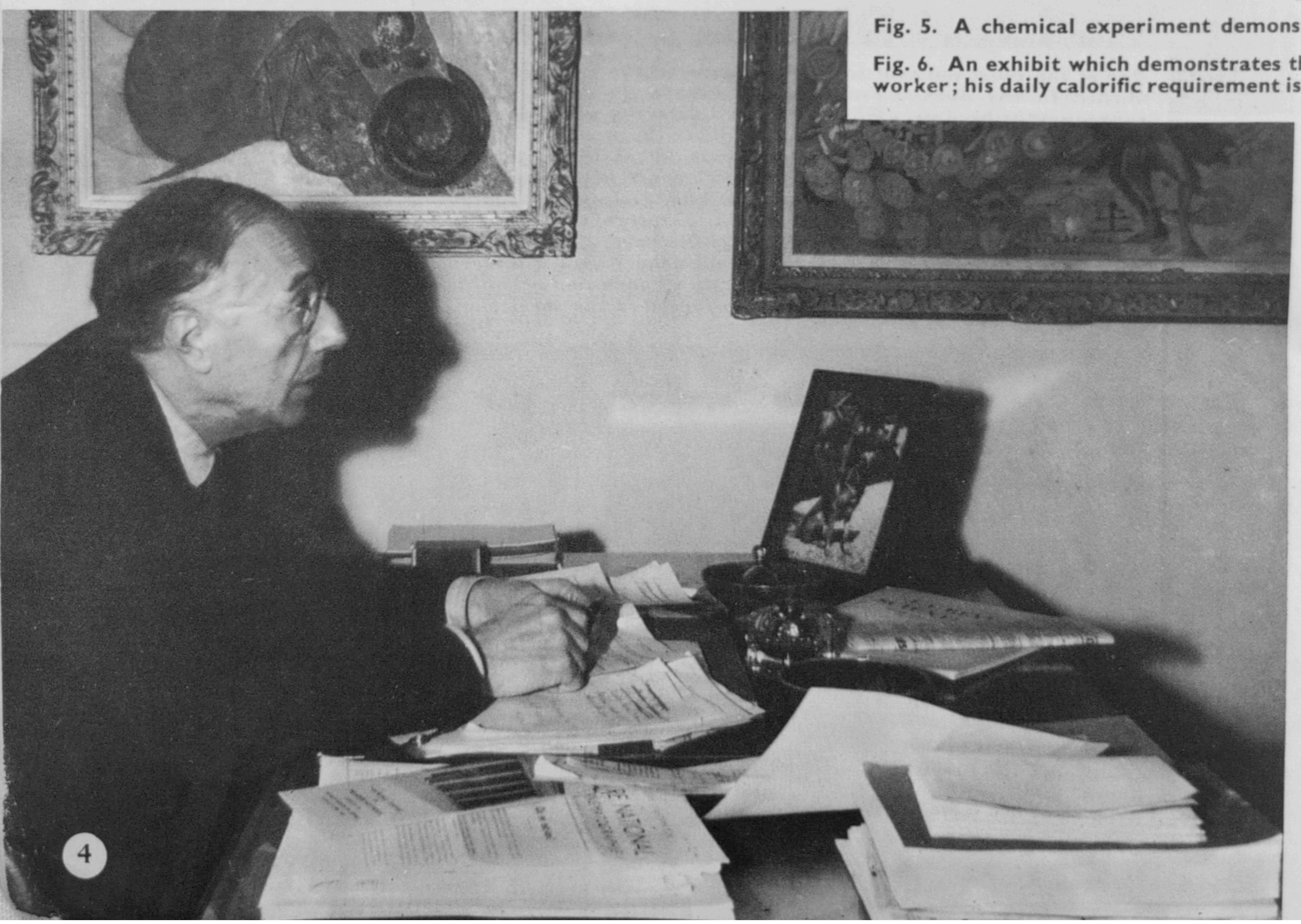

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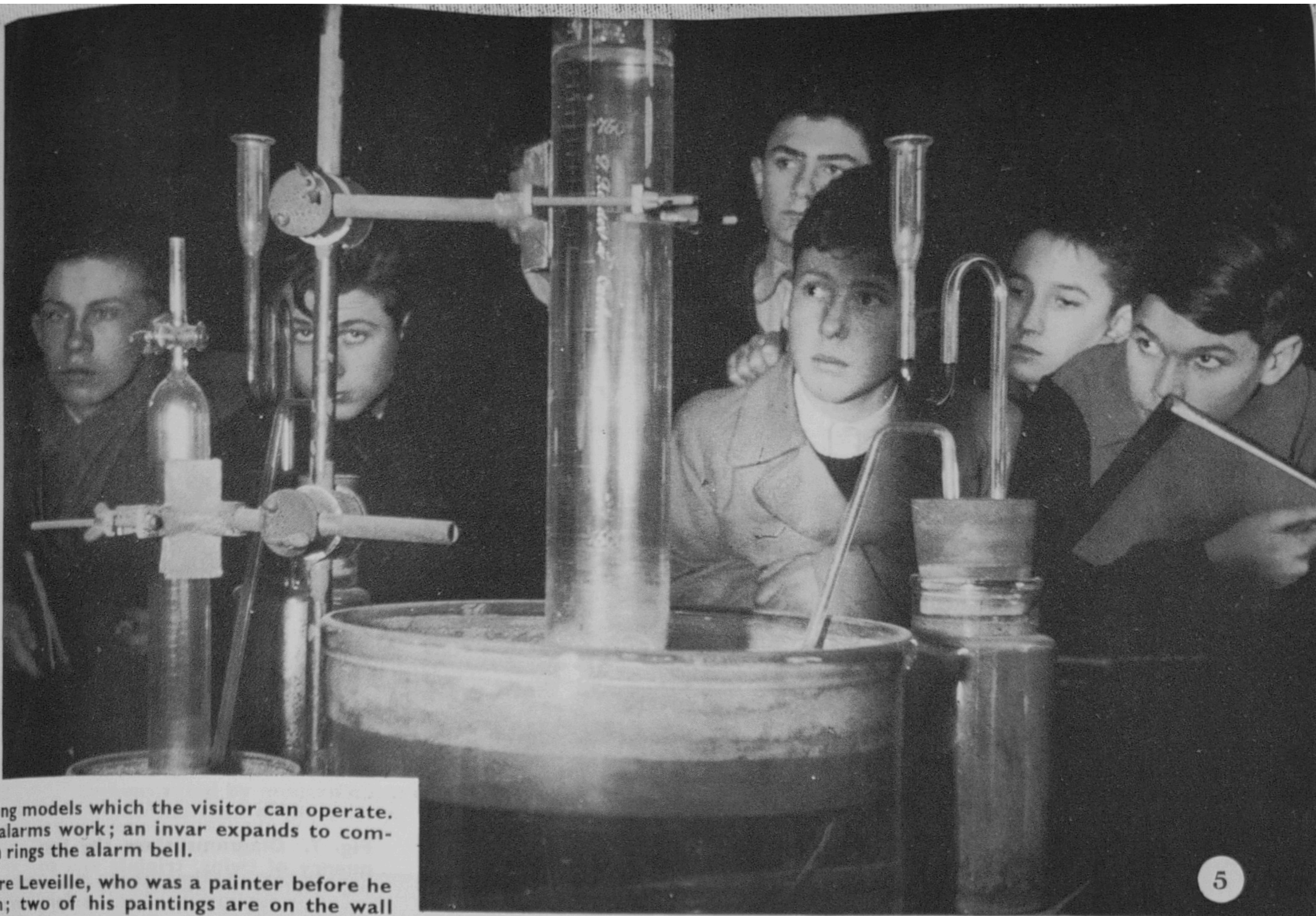
Fig. 3. The Palace of Discovery specialises in
This particular apparatus demonstrates how
plete an electrical circuit

Fig. 4. The Palace of Discovery is directed by
took on the organisation of this science
behind

Fig. 5. A chemical experiment demonstrates

Fig. 6. An exhibit which demonstrates the
worker; his daily calorific requirement is



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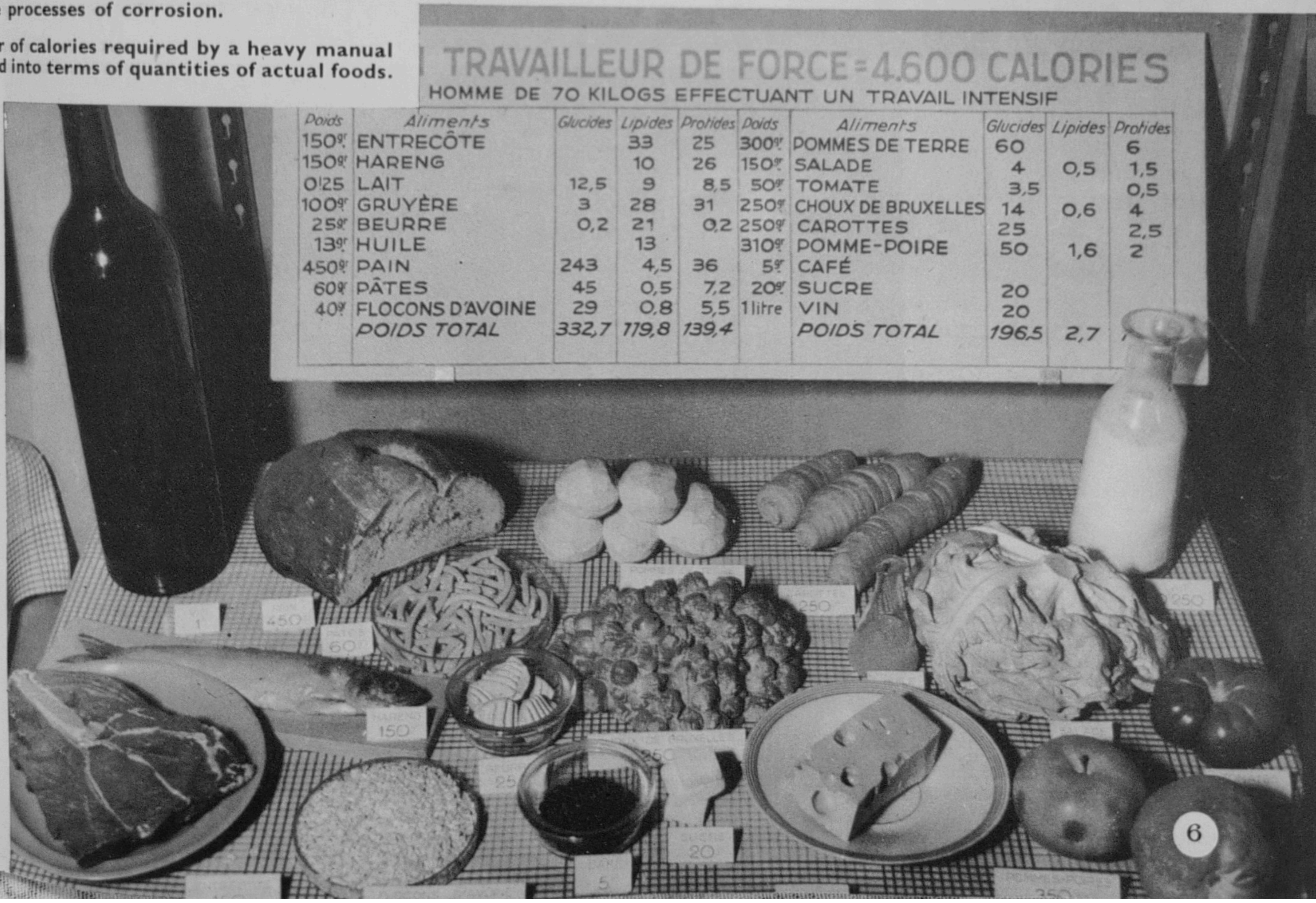
ting models which the visitor can operate. alarms work; an invar expands to comh rings the alarm bell.

dre Leveille, who was a painter before he m; two of his paintings are on the wall m.

e processes of corrosion.

er of calories required by a heavy manual ed into terms of quantities of actual foods.



TRAVAILLEUR DE FORCE=4.600 CALORIES

HOMME DE 70 KILOGS EFFECTUANT UN TRAVAIL INTENSIF

Poids	Aliments	Glucides	Lipides	Protides	Poids	Aliments	Glucides	Lipides	Protides
150gr	ENTRECÔTE		33	25	300gr	POMMES DE TERRE	60		6
150gr	HARENG		10	26	150gr	SALADE	4	0,5	1,5
0l25	LAIT	12,5	9	8,5	50gr	TOMATE	3,5		0,5
100gr	GRUYÈRE	3	28	31	250gr	CHOUX DE BRUXELLES	14	0,6	4
25gr	BEURRE	0,2	21	0,2	250gr	CAROTTES	25		2,5
13gr	HUILE		13		310gr	POMME-POIRE	50	1,6	2
450gr	PAIN	243	4,5	36	5gr	CAFÉ			
60gr	PÂTES	45	0,5	7,2	20gr	SUCRE	20		
40gr	FLOCONS D'AVOINE	29	0,8	5,5	1 litre	VIN	20		
	POIDS TOTAL	*332,7*	*179,8*	*139,4*		*POIDS TOTAL*	*196,5*	*2,7*	

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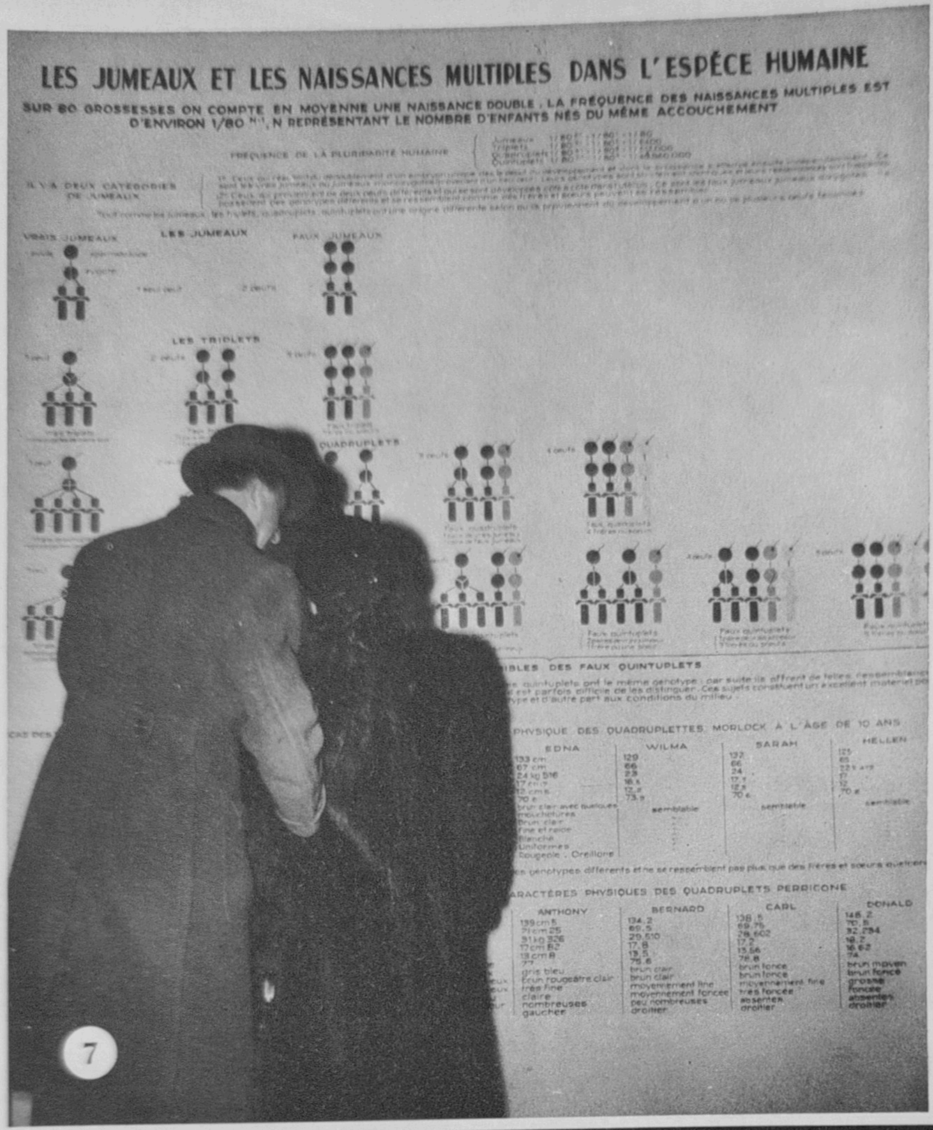
LES JUMEAUX ET LES NAISSANCES MULTIPLES DANS L'ESPÈCE HUMAINE
SUR 80 GROSSESSES ON COMPTE EN MOYENNE UNE NAISSANCE DOUBLE . LA FRÉQUENCE DES NAISSANCES MULTIPLES EST D'ENVIRON 1/80 N-1, N REPRÉSENTANT LE NOMBRE D'ENFANTS NÉS DU MÊME ACCOUCHEMENT
VRAIS JUMEAUX
LES JUMEAUX
FAUX JUMEAUX
LES TRIPLETS
QUADRUPLETS
DES FAUX QUINTUPLETS
PHYSIQUE DES QUADRUPLETTES MORLOCK A L'AGE DE 10 ANS
EDNA
WILMA
SARAH
HELLEN
CARACTÈRES PHYSIQUES DES QUADRUPLETS PERRICONE
ANTHONY
BERNARD
CARL
DONALD
7

Fig. 7. Diagrams show the frequency of twins, triplets and so on. Mendel's Laws are also well explained by exhibits in the Palace of Discovery.

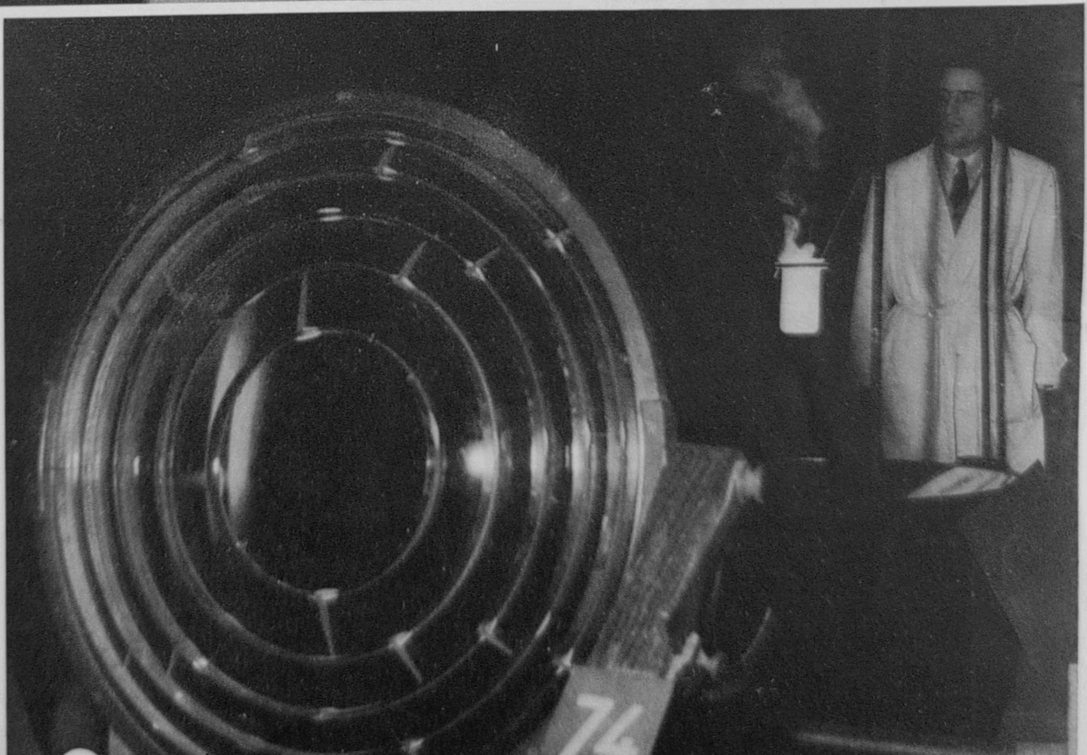

Fig. 8. In this demonstration in the Hall of Optical Science, radiation from the filament of an electric lamp is focused by two large spherical mirrors and is used to boil a flask of water.

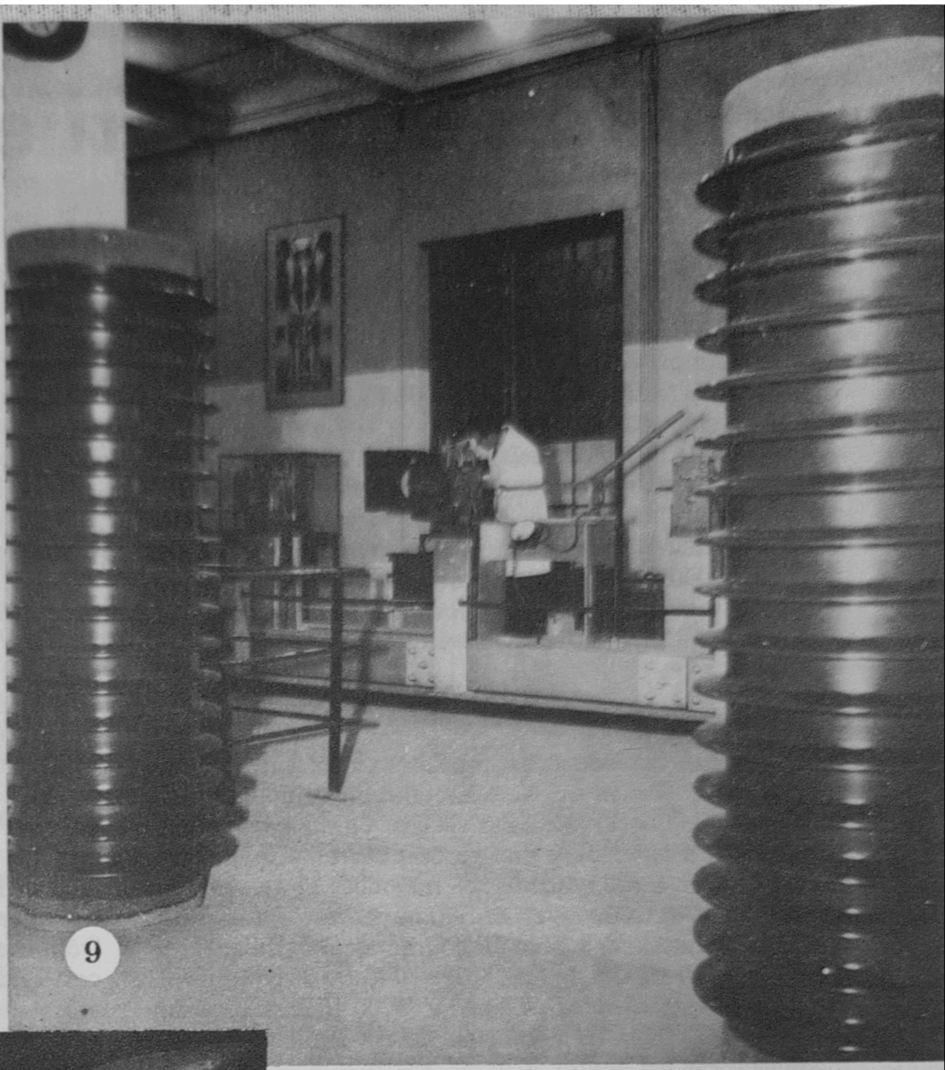

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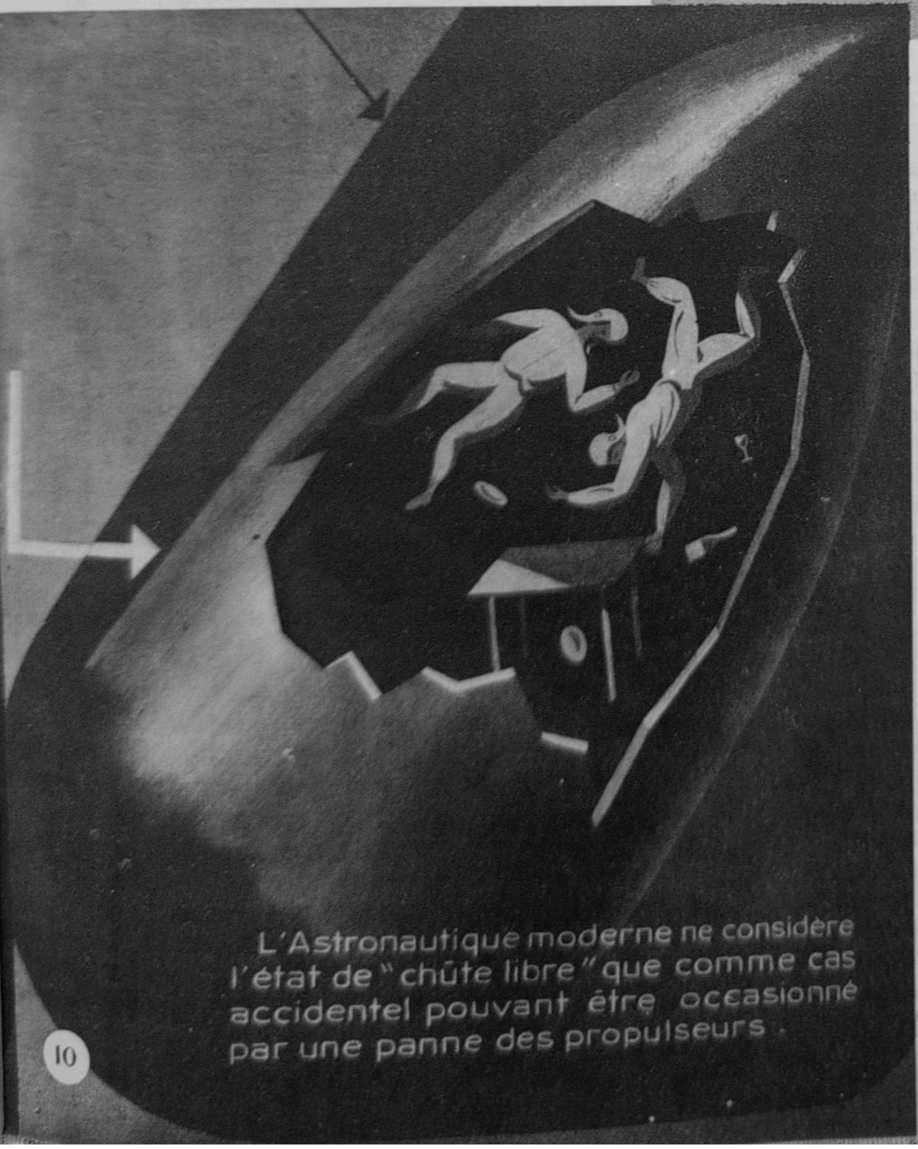
Fig. 9. Basic electrical principles are demonstrated by modern apparatus in the Hall of Electricity.


L'Astronautique moderne ne considère
l'état de "chûte libre" que comme cas
accidentel pouvant être occasionné
par une panne des propulseurs.

10

Fig. 10. The Palace of Discovery not only deals with current and past achievements of science; it also delves into the future, as with this exhibit about interplanetary travel and the difficulties which it will inevitably involve.

Energy in the Future*

PROF. F. E. SIMON, F.R.S.

Clarendon Laboratory, Oxford

CIVILISATION as we know it is only made possible by an abundant supply of energy. Shall we always have enough energy at our disposal to keep it going? Shall we have enough to cater for an increase in the world's population and to provide the under-developed areas of the earth with the means of raising their standards of living? In attempting to answer such questions many diverse problems have to be considered besides the purely technical ones, in particular what will be the future political structure of the world. Let us assume, however, for the sake of argument—and of the world—that it will develop on reasonable lines.

A Few General Considerations

First, one or two somewhat fanciful examples to give the right perspective. If we were to take all humanity and smear them out over the land surface of the earth, they would form a layer only one-thousandth of a millimetre thick. Or, for those who dislike this idea: if we were to compress all the 2000 or 2500 million people on the earth into a solid mass they would all go into a cube whose sides were only 500 metres long. The well-known pyramid of the Matterhorn rising up from the 3000 metres contour could contain them all about ten times. From the many manifestations of energy around us, solar energy, wind, water, temperature differences, it should be obvious without any detailed discussion that this thin layer of humanity need never go short of energy. The earth intercepts as much energy from the sun in ten minutes as its inhabitants use in a year. Thus even if the world's population were to increase to the limit set by the possible food supplies, and even if there were in addition a big increase in the energy consumed per person, we should never be short of energy sources.

However, it is not enough to say that ample energy sources exist, we must consider how convenient and practical it is to tap them. One point of great importance is their degree of 'concentration'; obviously energy sources like the tides, which need enormous installations to harness them, are inferior to those in which the power is more concentrated. Then there is the question of transporting energy over long and short distances. (Before the advent of electricity it was only possible to transfer energy a distance of up to a few hundred yards, so all power plants had to be built near the consumer plants.) Finally, we have the problem of storing energy. This is obviously easiest with fuels (i.e. chemical energy), more difficult with water and impossible with wind. These considerations have so far greatly favoured fuels as sources of energy, and the Industrial Revolution was built entirely upon their easy availability.

There are not really many sources of chemical energy left, as most of the possible chemical reactions had already taken place a few hundred million years ago, when the earth was very hot. From the chemical point of view our globe is practically burnt out. The only exceptions are the remains of former organic life, laid down at a very late period in the earth's history under more or less chance conditions which have favoured their preservation. These stores are naturally strictly limited. If we were to smear out over the surface of the earth the present known stores of coal and oil they would form a layer about 1 cm. in height, representing energy which at the present rate of consumption would last for a few thousand years.

Thus, although we are obviously living off capital, there seems at first sight to be no urgent need to open up new sources of energy. However, we have to consider other factors. In order to raise the world's standard of living it will be necessary to increase considerably the amount of power consumed per person, but it is difficult to predict at what rate this will happen. If, however, the increase that we have seen in the last few decades should continue, our supplies might last only several hundred years. Then again our fuel stores are very unevenly distributed over the surface of the earth, and even assuming that in a future unified world free exchange will be possible, countries far away from the mines or oil wells will still be handicapped by the cost of transport. Lastly, in a free society it will become more and more difficult to get people to spend the greater part of their active life underground in not very congenial surroundings.

Another point of importance: without going into much detail, one can say with certainty that we cannot expect any spectacular changes in the *price of power* owing to the development of new sources of fuel. Only a small part of the price the consumer has to pay for energy is due to the cost of the fuel (roughly about one-sixth in the case of electricity produced by burning coal). The rest goes towards the cost of the power station and, in particular, the distribution system. The coal-fired power station has reached a high degree of perfection and it is difficult to see how the generating plant for any other form of power could cost appreciably less. It is clear therefore, that even if we were to find a fuel which costs nothing, there would be no spectacular drop in the cost of energy to the consumer. Similarly it is unlikely that there will be any major changes in the upward direction. After all coal is certainly available for the next few centuries, so if some new source of power is much more expensive, it simply will not find many consumers, even though it may offer a few special advantages.

Different Kinds of Energy: The First Law of Thermodynamics

To discuss our problems intelligently we first have to survey the different forms of energy and their convertibility into each other. Even though we talk about 'producing' energy, we actually can only convert one form of it into another. The indestructibility of energy has been recognised for about 100 years and is expressed as the *Law of the Conservation of Energy*, also called the *First Law of Thermodynamics*. It is perhaps best known to the layman as the dictum that it is impossible to construct a perpetual-motion machine, the despair of so many inventors.

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* This article is the essence of a report prepared by Prof. Simon for Unesco. The notes on nuclear energy and solar energy have, however, been extended and various small modifications made.

There are two quite different kinds of energy which we must distinguish, free energy and heat energy. *Free energy* is energy in an ordered form like the mechanical energy of moving masses or rotating shafts, or electrical energy. Chemical energy is to a great extent free energy: in the case of the reaction in which we are most interested, that of the combination of the carbon in coal with the oxygen in the air, we can say that practically all this energy is free energy, comparable to the energy stored in a stretched spring. *Heat*, on the other hand, is due to the disordered motion of the smallest particles of matter, the atoms and molecules. This disordered motion only ceases at the so-called absolute zero (—273° on the centigrade scale) and the energy of the atoms to a first approximation is proportional to the temperature counted from this point.

According to the law of the conservation of energy, there is a definite rate of exchange between the different forms of energy measured in their respective units. It will be useful for us to get an idea of the order of magnitude of the most important of these rates of exchange, that which governs the change of mechanical energy into heat. When a falling body hits the ground, its ordered, directed motion is converted into disordered motion of the atoms. When a mass of a kilogramme falls a metre it gains 1 metre kilogramme of free energy of motion; if it then strikes the ground this energy appears as 2·34 calories of heat; in the case of water this heat would raise its temperature by 2·34/1000° C. The waters rushing down Niagara, with its fifty-metre fall, leave it 1/8° C. warmer! The smallness of these effects explains why it took such a long time to discover the law of the conservation of energy; there were so many examples where energy obviously 'disappeared'. The explanation of this very low rate of exchange is that the velocities we are used to in normal life are very small compared with the disordered velocities of the atoms. The heat generated by the friction in the brakes when stopping a motor car driven at 60 km./hr. would only be sufficient to increase the average temperature of the car by 0·3°, which means that the energy of the car at that speed is only one-thousandth of the energy of the thermal motion. Thus, even if the whole of this heat is generated in the brakes, only quite tolerable temperature changes occur there.

There is a reverse side to this picture: namely that the amounts of heat energy we are accustomed to use in industry and in our houses correspond to enormous mechanical energies. In order to have a bath a man needs to heat say 100 litres of water through 30°, which requires some 3 million calories of heat energy. These 3 million calories in the form of free energy would lift him a vertical distance of 20 km. or five times the height of Mont Blanc above Chamonix. Thus if he had to warm his 'daily' bath water by his own *mechanical* efforts he would have to work as hard as he could for a whole week to get one bath—by the end of this time he would no doubt badly need it! Even to heat the air in a room just once through the normal temperature differences in winter would correspond to the work a man could do in about a day—and on the average the air in a room is changed about three times per hour. These illustrations show us how important it is to be economical with heat energy both in the home and in industry.

Though in theory all types of free energy are fully convertible one to another, there are often practical difficulties in doing so. It is easy to convert mechanical into electrical energy with a high efficiency using a dynamo and vice versa (electric motor), but there are only a few practical mechanisms for converting chemical energy into mechanical or electrical energy. This can be done for a few chemical reactions by using galvanic cells but the necessary 'fuels' do not occur naturally, and have themselves to be prepared artificially with a consumption of energy. The living body can convert organic fuels, albeit rather complex ones, into the free energy of muscular movements with an efficiency of up to 50%. So far however, no practical way has been found to convert the energy of coal or oil directly into other forms of free energy by using the hypothetical 'fuel cell'. Thus we are forced, as a first step in using this chemical free energy, to let it deteriorate into disordered heat energy by burning the fuel and then try to save what we can from the débâcle. It is as if water turbines had not been invented and we could only turn the water power of Niagara into mechanical energy by letting the water warm up by falling freely and then using the heat to drive a heat engine. Of course in this case the temperature rise is very small, while when we burn chemical fuels the energy 'falls' much further and produces higher temperatures, which enable us to get a useful amount of power from the system. Yet in principle the two processes are similar.

Conversion of Heat into Free Energy: The Second Law of Thermodynamics

We must now consider the all-important question of how to convert heat back into some form of free energy. The opposite process of converting free energy into heat is very simple indeed as it means the conversion of order into disorder, and as everywhere in life it is much simpler to create disorder than order. Mechanical or electric frictional processes bring about the deterioration of free energy into heat in a very simple way. But nobody would expect to see a car start up without the help of the engine while as compensation the brakes cool down, although this process would not incur the veto of the law of the conservation of energy. Nor would they expect to see a person thrown 20 km. up in the air from his bath while the water cooled down in compensation. Nature moves so as to get into the most *probable* state and the disorder of heat energy is much more probable than the order of, say, mechanical energy. Nevertheless, it is possible to convert a certain amount of heat into free energy and the so-called *Second Law of Thermodynamics* tells us how we may do this. There must be temperature differences at our disposal, and only a part of the heat which we put in at the high temperature can be converted into free energy; the remainder reappears as heat at the low temperature. It is therefore useless to try to build a machine which draws on the heat energy of its surroundings. Though such a machine would not contradict

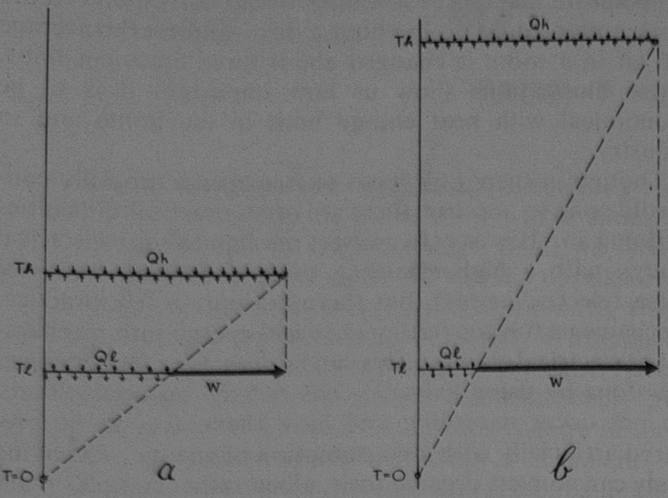

FIGURE 1

the First Law it would still be just as useful as a perpetual-motion machine since there are such vast stores of thermal energy all around us. It is therefore called a perpetual-motion machine of the second kind, and while most 'inventors' no longer trouble with a machine of the first kind, the impossibility of constructing one of this second kind has not yet penetrated to a fair number of them.

The Second Law also says that under the best conditions, when all frictional processes are avoided, the quantity Q_h of heat put in at the high temperature divided by that temperature T_h, is equal to the amount (Q_l) of heat reappearing at the low temperature T_l over that temperature. Hence the amount of free energy at our disposal is given by:

$$W = Q_h - Q_l = Q_h \frac{T_h - T_l}{T_h}.$$

The relation $Q_h/T_h = Q_l/T_l$ is illustrated in Figure 1. The amount of free energy which can be taken out of the system is given by the thick line W. By comparing Figures 1a and 1b one can see how the efficiency W/Q_h increases with rising temperature.

It is therefore the alpha and omega of all designers of heat engines to supply them with heat at as high a temperature as possible and also to remove it at as low a temperature as possible, which in practice means at a temperature as little above that of the surroundings as possible. Fuels produce much higher temperatures than the materials now at our disposal can withstand; the development of more efficient heat engines depends therefore either on the development of new materials for use at higher temperatures, or on designing engines whose metal walls do not take up the temperature of the hot working gases (as is already done in the internal combustion engine). The best practice at present gives efficiencies of about one-third, which means that one-third of the heat energy supplied to the system appears as free energy.

Although only a small part of the chemical energy in fuel is finally transformed into mechanical energy, relatively small volumes of it produce considerable amounts of mechanical energy. The chemical energy stored in a cigarette, if converted completely into mechanical energy, would lift a man about 20 metres! A tank full of fuel in a motor car takes us at a considerable speed for 500 km. or so, which implies that the energy released by the rearrangement of the forces between the atoms is very large. Indeed in burning fuel, temperatures of the order of 2000° C. are generated and as we have seen before, this corresponds to molecular velocities very much higher than the velocities we are used to in normal life.

The Heat Pump

There are occasions when we want quantities of heat at quite low temperatures, as for heating our homes. It follows from what we have already said that, if we get this heat from free energy, we can do so very economically by reversing the operation of a heat engine. As an example let us consider the steam engine which we normally use to produce work. Heat is supplied to the boiler at the high temperature to evaporate water into steam. The steam expands producing mechanical work, and is finally condensed to water again at ambient temperature. This last process in the condenser delivers heat to the surroundings which act as the low temperature sink. Suppose now we run this engine in reverse. We let the water evaporate at the low temperature, and then put free energy into the resulting vapour by compressing it. As we compress it the temperature rises, and we finally condense the vapour and discharge heat energy to the condenser at this high temperature. The amount of mechanical work we have to put into the system is now given by the same formula which we still write as:

$$W = Q_h \frac{T_h - T_l}{T_h},$$

but W is now the work we must do to *produce* heat Q_h at the high temperature. The smaller the temperature difference the less free energy we need. If for instance we take a temperature difference of 20° then we have only to put in $20/300 = 1/15$ of the free energy which would be required to produce the same heat by friction. This is of course not in contradiction to the law of the conservation of energy; the other fourteen-fifteenths of the energy needed is taken from the thermal energy of the surroundings at the low temperature end.

Machines of this type, although not using water as the liquid, are quite common: they are called refrigerators. These create a temperature difference between the surroundings and an insulated box which becomes cold; a motor is used to supply the free energy needed to transfer heat from the cold box to the higher temperature of the machine's surroundings (Fig. 2a). If, however, we shift the levels as in Fig. 2b we may take heat from a large source, say from the water of a river, and deliver it to a box or room which we wish to keep at a higher temperature. In this case the arrangement is called a 'Heat Pump' because, so to speak, we 'pump' the heat from the temperature of the surroundings to the higher level. To repeat: if we have 1 kilowatt hour available in the form of electrical energy, we can use it for heating purposes in one of two ways: (*a*) we may simply convert it directly into heat by electrical friction, using the ordinary radiator and receive 1 kilowatt hour of thermal energy, or (*b*) we may use it to drive a heat pump, which under the conditions mentioned would deliver 15 kilowatt hours of heat to our room. This figure assumes all the machinery to be working ideally; with the losses inevitable in practice the performance would be about half this.

If such big savings can be effected, why is the heat pump not in general use, at least in countries which derive their energy mainly from water power and not from fuels? The reason is that the ordinary type of electrical heater is a very simple and cheap apparatus, while the heat pump with its evaporators, compressors and condensers is much more expensive and complicated. This is yet another illustration of the fact that it is very simple to create disorder and very difficult to remove it. Mankind has for many thousands of years been able to produce temperatures of 1000° C. or higher, but the refrigeration industry is a product of the last few decades. Even today refrigerators are complicated and expensive while an electric torch costing a few pence produces temperatures of 2000° C.

The Utilisation of Energy

Energy is used in different parts of the world for very many different purposes and no generally valid analysis is possible. Roughly speaking, however, we can say that in an industrialised country about 25–30% of the total power consumption goes for domestic use (most of it for space heating), 30–40% to industry (again to a great extent in the form of heat), 20% for transport and the remainder in a variety of miscellaneous ways. Thus a very considerable part of all the energy consumed is used in the form of heat. Let us now apply the considerations of the previous sections to see how much of this energy we waste.

Space Heating

The best use we could possibly make of a kilogramme of coal would be to convert its chemical free energy directly into electrical energy in a fuel cell, and then use the electricity to drive a heat pump which heats our room. In order to get the same amount of heat by using a coal fire in the house we would need to burn 15 kg. of coal in a stove that did not waste any of the heat (e.g. up the chimney). With a good central heating system about 75% of the heat is utilised, i.e. we must burn 20 kg. of coal, so the efficiency of this system is only 5% of the best possible. Even a good stove wastes more heat than this and its overall efficiency falls to 3% while the very wasteful open fireplace used as the main source of heating in England has an efficiency of only 1%! If we heat our houses electrically we throw away at the power station all but one-fifth of the energy of our fuel and then convert the electricity into heat in our homes at an efficiency of one-fifteenth, i.e. the overall efficiency is one-fifteenth × one-fifth or a little over 1%. We repeat that these figures for efficiency give a comparison with the best performance possible in principle; the fact that efficiencies are not generally calculated this way does not change matters.

Some of this waste is at present unavoidable (for instance we do not yet know how to convert chemical energy directly into electrical energy without the intermediary of heat), but much could be done to reduce it. While electrical heating is a very convenient way of heating, it should never be used on a large scale. (The fact that one can easily switch it on and off will always lead to its application for some purposes and its cleanliness recommends it for, say, the heating of hospitals.)

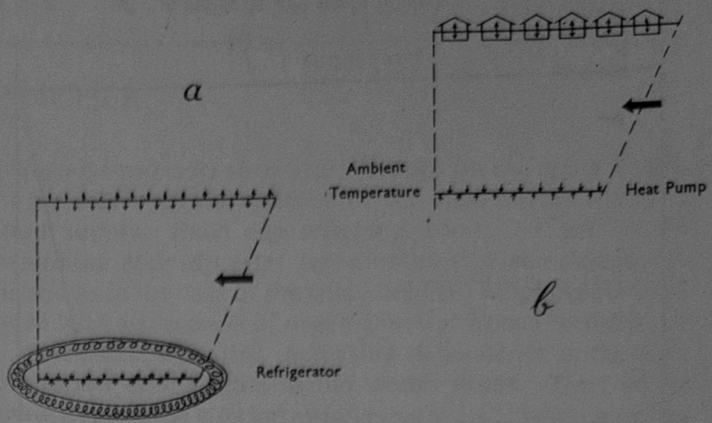

FIGURE 2

Open fires should be abolished, particularly as they are also the worst offenders from the point of view of producing dust and dirt. All new houses should be fitted with either central heating or an efficient stove and the existing fireplaces should be replaced by simple stoves designed to take their place.

By far the best way of heating would be district heating coupled to an electrical power station. We have seen that a power station gives up the greater part of the energy supplied to it from the fuel as low-grade heat, and the lower the temperature of this rejected heat the greater the efficiency of the plant. Normally this heat is given up at the temperature of the surroundings and is of no further use, but if it is rejected at a slightly higher temperature, say at 80° C., it could be used for space heating. The power plant would of course run at a somewhat lower efficiency, but there would be a great overall saving of energy as the rejected heat would now be employed usefully as illustrated in Fig. 3. In this type of plant the steam is not condensed in a condenser but leaves the turbine at a higher temperature and pressure ('back pressure turbine') and is then used for space heating. This gives the same efficiency as if we ran the plant with a condenser and then used some of its output to drive a heat pump to supply the space heating. In actual practice the 'back pressure' system would be superior as it is much simpler. Therefore from the thermodynamic point of view—and this is also of course the point of view of coal economy—it is at present the most efficient method of space heating.

The advantage we gain by taking work from our fuel before using it to heat our houses is of course greatest when the prime mover has a high efficiency. As small power units have a low efficiency, the use of 'back pressure' turbines is only economical with very big units and this means that direct heating with back pressure turbines is necessarily restricted to a few big cities. The enormous amount of energy which can be saved in this way makes it highly desirable to devise small power units with a high efficiency so that the benefits of this method of heating could be extended over the whole country.

Where at present electricity is generated in hydro-electric stations and used for heating purposes, the installation of individual or district heat pumps should produce a

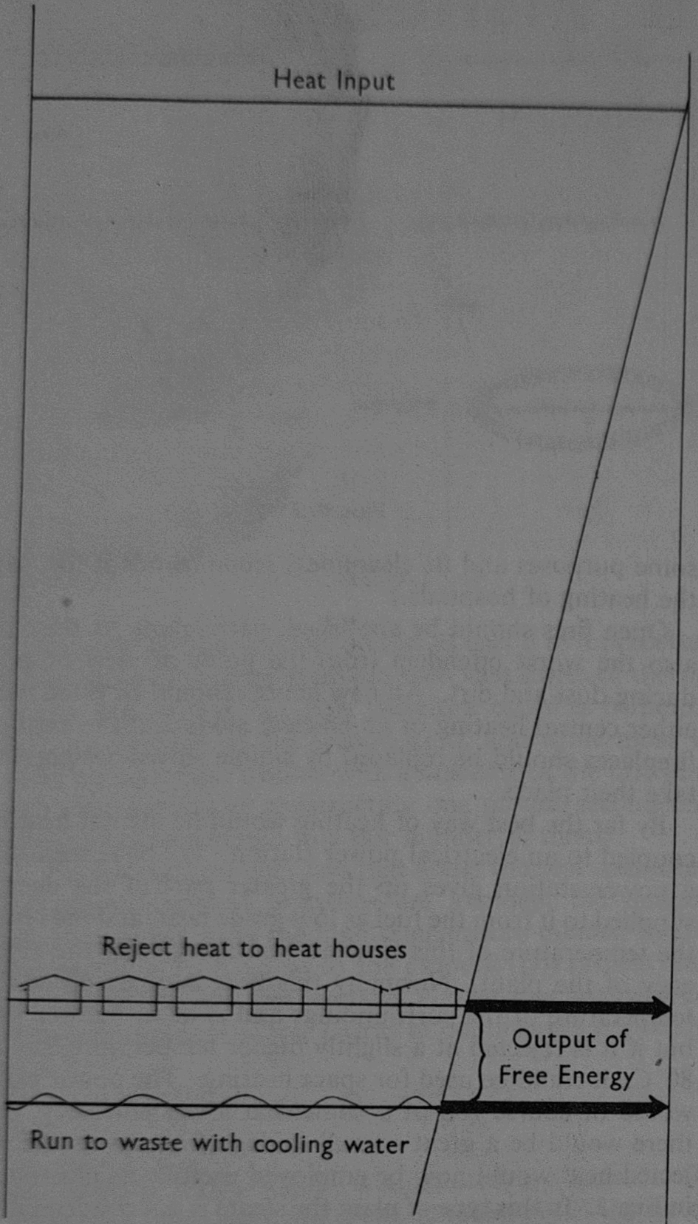

FIGURE 3

large saving. Most countries, however, have coal-burning generating stations in which 75 or 80% of the energy of the fuel is immediately lost. If we use the electricity to drive a heat pump, we do in fact deliver to our homes a little more heat than can be got by burning the coal. This gain is, however, quite small and the capital expenditure on generators and heat pumps is considerable. Thus it is more economical to obtain space heating by burning the coal in an efficient central-heating system. Individual heat pumps might, however, have a future in countries where they are used in winter for heating and in summer for cooling purposes. In this case the initial high expenditure may be justified, at least for the well-to-do part of the population.

Efficiency in Industry

There is also some scope for heat pumps in industry in processes which need only small temperature differences, for example in the evaporation of solutions and in the concentration of fruit juices or similar products. A certain number of such plants working with the so-called 'vapour recompression' cycle, a special version of the heat pump, are already in use.

In industry generally heat is utilised with only low efficiency. One need only have a look at a Bessemer converter to realise this. Another example of waste of heat is a foundry; in changing the form of a piece of material, we loosen the bonds of *all* atoms in the metal while in principle it would only be necessary to loosen those near the new surface. It is easy to calculate that we use more than a million times more energy than is in principle necessary.

Let us now very shortly discuss a few systems designed to produce free energy and begin with the *prime movers*, i.e. heat engines which give mechanical work. The best machines at present have an efficiency of 30–35% which, compared with other processes, is not at all bad. Future gas turbines might give up to 50%, but higher values will probably only be possible with the fuel cell. One exception in this not too sombre picture of the prime movers is the locomotive, which has an average efficiency of only 5%. Fortunately it is now being progressively replaced either by the electric or diesel engine and relatively soon the 'efficiency' of rail transport will approach that of the motor car, i.e. about 20%. An encouraging pièce of information is that one of the biggest American locomotive factories has decided to build no more steam engines —to the great dismay of small boys of all ages.

In producing *light* in the ordinary bulb we make use of about 3% of the electric energy, while fluorescent lighting makes use of up to 10% of it. *Chemical and metallurgical* industries utilise their energy with about 5–10% efficiency. While these are only a few examples many more could be given from all branches of industry.

It may here be the place to insert a general remark. Schemes to save energy nearly always imply an initial capital expenditure, as an efficient system is usually a more complicated one. We have discussed this already in the case of the ordinary electrical heater and the heat pump, but the principle is applicable generally. In every practical system we have to strike a balance, and we should not go too far to either side. Let us consider just one example. When decelerating a car the energy could in principle be stored and used again for the next start. We would, however, have to incorporate complicated and bulky machinery (say dynamos and batteries or flywheels) to replace the brakes. Life would become very complicated indeed if we could not 'get rid' of energy by simple frictional processes. Where the compromise solution lies will depend on very many factors and will change with the progress of technique. It is clear, however, that in the utilisation of heat we have gone much too far to the side of simplicity, perhaps because of the former cheapness of coal.

If we average the *efficiency of power utilisation* in all fields of human activity (using the standards of efficiency described above), it turns out that the total utilisation is of the order of 4–5% (in England about 3–4%). Of course nothing approaching 100% efficiency could be attained in practice, but if we only increased the efficiency to 10% it would mean that we would need less than half of the power consumed at present. Such reduction is possible if we apply only our present knowledge. (*This article will be concluded in the May issue of* DISCOVERY.)

Vivipary in Fishes

CHAPMAN PINCHER

THE eggs of all cartilaginous fishes—the sharks, skates and rays*—and those of many bony species are fertilised inside the body of the female.

Since the life of an individual fish begins at the moment of conception, all species with internal fertilisation are viviparous, for the usual definition of this term is 'bringing forth young alive' and any fertilised egg which subsequently develops must be alive when it is laid.

A better definition would be simply 'bringing forth young' where 'young' implies one or more embryos at such an advanced stage of development that they are capable of active and independent existence.

This would exclude such forms as the skate (*Raja batis*) and common dogfish (*Scyllium canicula*) which extrude their eggs in horny cases soon after fertilisation.

Viviparous fishes show all grades of relationship between embryos and mother.

The simplest condition is shown by the spiny dogfish (*Acanthias vulgaris*) common off our coasts. In this species the oviducts are expanded into womb-like structures in which the eggs lie freely, bathed in a fluid (Fig. 1). The fluid is secreted by long threads hanging from the lining of the 'wombs'. That it makes important contributions to the development of the embryos is shown by a comparison of the weight of a fertilised egg—about 23 gm.—with the weight of a young fish at birth—about 41 gm.

Analysis shows, however, that this increase is due mainly to the absorption of water. The weight of organic matter originally in the egg actually decreases from about 8·6 to 5·2 gm. by the end of gestation. This does not necessarily mean that no organic nutrient is absorbed from the womb fluid, for the total loss due to combustion during development may be more than the obvious 3·4 gm. deficit. But it does indicate that the contribution of organic material by the fluid is small.

One very important aspect of the fluid's function is its value as a carrier of oxygen, without a constant supply of which the egg cannot develop. (The eggs of oviparous forms like the common dogfish and skate are also to some extent dependent on the outside environment. In addition to oxygen they obtain about 70% of the water and 60% of the minerals they must have to complete development.)

Fig. 2 shows a young spiny dogfish with a partially absorbed yolk-sac taken from a pregnant female. By the time it is ready to be born the fish has entirely absorbed the yolk through a tube leading direct to its intestine. Its mouth is then open and it is in all essential features a miniature of its parents. So perfect is it that if taken from the oviducts of a freshly caught female some days before it is due to be born, and placed in sea-water, it will immediately begin to swim. (The ultimate state of pre-natal development is shown by the male surf-fish (*Cymatogaster aggregatus*) of Californian coasts which is fully mature sexually at birth.) The females are inseminated soon after birth but fertilisation is delayed about five months, the sperms being stored meanwhile. The smooth dogfish (*Mustelus vulgaris*) shows an advance on the spiny species in the increased dependence of the eggs on the maternal food supply. Each egg weighing about 3·9 gm. at the beginning ends up after ten months (the same gestation period as in the case of the spiny dogfish) weighing 60·6 gm. or so with an *increase* of organic matter from 1·9 to 8·9 gm.

Correlated with this increasing dependence is the concentration of nutrients in the womb fluids. Thus in the spiny dogfish the concentration is only 2·4% whereas in the smooth species it is 5·1%. In those fishes where dependence is very great, the fluid is not only very rich in dissolved nutrients but contains suspended solids reaching in the case of the violet sting-ray (*Trygon violacea*) a total concentration of 13·3%.

That such a concentration of nutrients is required is shown by a comparison of the weight of the egg of the violet sting-ray—about 2 gm.—and the weight of the embryo at birth—118 gm.

It seems that this food is obtained at the expense of the mother's liver, for in viviparous cartilaginous fishes the weight of the maternal liver is considerably reduced during gestation. The more dependent the young are on the maternal food supply, the greater is the liver's weight loss.

Investigation has shown that in many viviparous species the liver is considerably richer in oil during gestation than at other times. The oil content of the liver of the common skate, for instance, rises from 22% to 52% during pregnancy.

A few bony fishes like the salmon, trout and eel have ovaries like those of the dogfishes and sharks in which the eggs are extruded from the surface into the body cavity whence they make their way into the oviducts. All viviparous bony species, however, have the more usual types of ovaries—hollow sacs bearing small cavities or 'follicles' on their inner linings (Fig. 3). A few, the surf-fish for example, have the ovaries united to form a single sac.

Each follicle contains an egg and its wall splits allowing the entry of sperms introduced by the male, which has some form of intromittent organ—commonly a modification of the anal fin. Having been fertilised in the follicle, the egg may complete its development there, the follicle enlarging to accommodate the embryo. Or as happens in quite a few species, the eggs may fall into the central cavity of the ovary and there develop. In some, e.g. the millions fish (*Girardinus poeciloides*), the final stages are completed in the oviducts.

The occurrence of viviparity is sporadic and the condition has obviously arisen many times in the evolution of fishes. Thus it occurs in every group of the cartilaginous fishes—the Elasmobranchs—and in many sub-orders of the Teleosts—the bony forms. Yet the devices developed by quite unrelated species to get food and oxygen from the mother's tissues to the young are often very similar, providing interesting examples of the phenomenon of *convergence*—the similar solution of a biological problem by unrelated animals developing independently.

In this connexion it is interesting to compare the sting-ray (*Pteroplatea micrura*), a large cartilaginous fish of the

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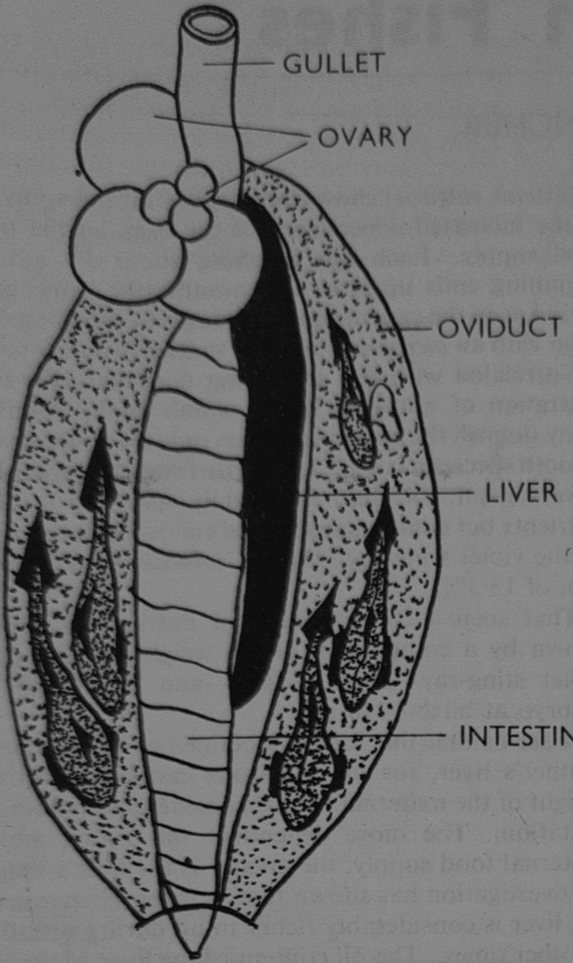
* With the single exception of the Greenland Shark.


GULLET
OVARY
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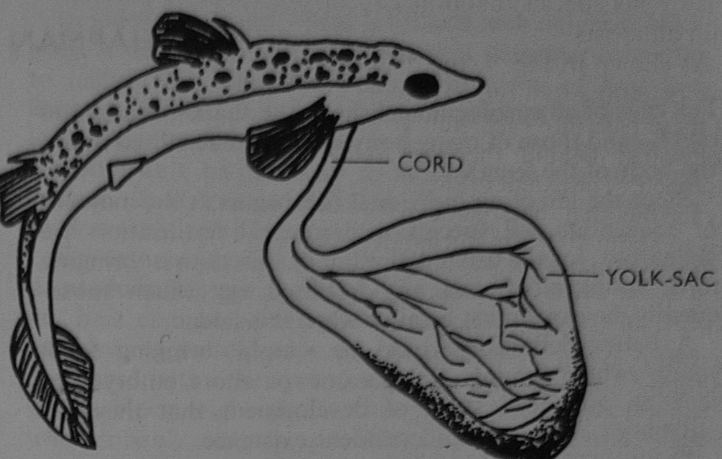

CORD
YOLK-SAC

FIG. 1 (*left*).—Reproductive organs of a pregnant spiny dogfish, with young developing in the expanded oviducts.

FIG. 2 (*above*).—A young spiny dogfish taken from its mother's body.

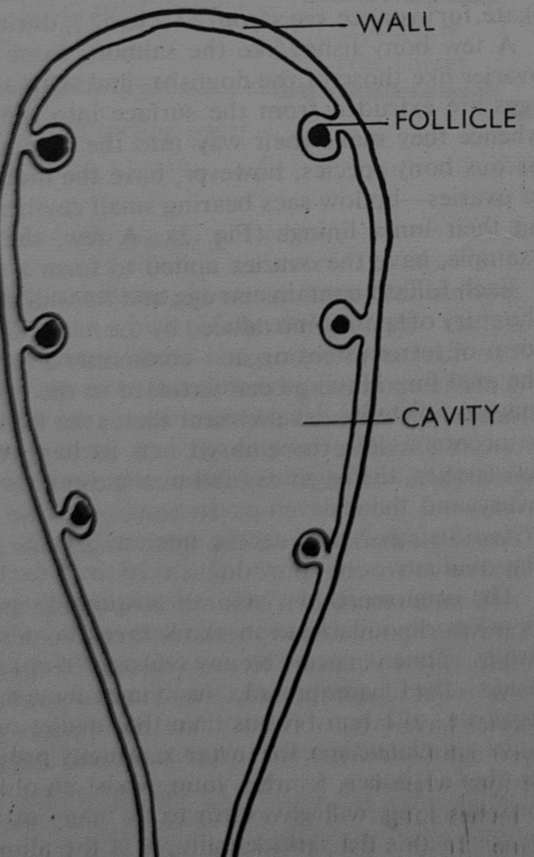

WALL
FOLLICLE
CAVITY

FIG. 3.—Ovary of a viviparous bony fish in section, showing the follicles in which the eggs develop.

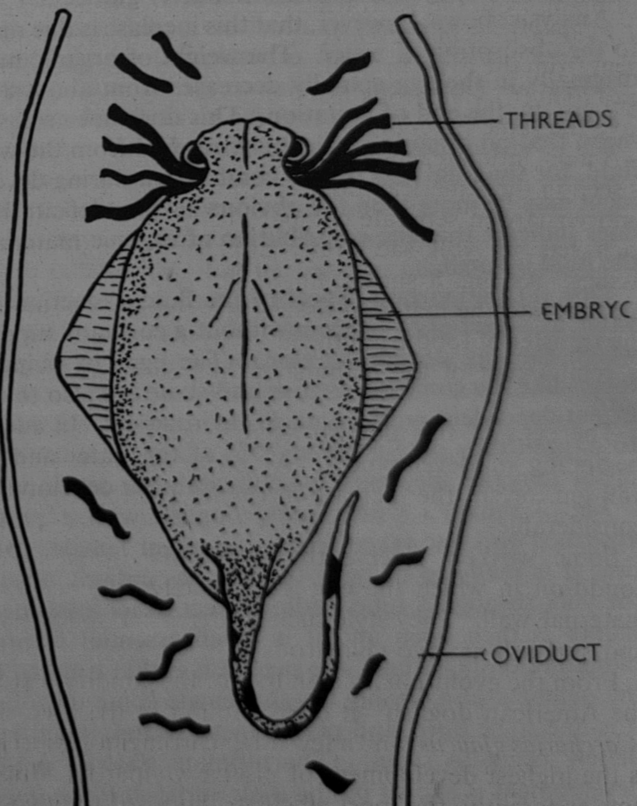

THREADS
EMBRYO
OVIDUCT

FIG. 4.—Embryo of an Indian sting-ray (*Pteroplatea micrura*) lying in the oviduct. Threads from the lining of the oviduct pass through the spiracles of the embryo and secrete food into its stomach.

Indian Ocean, with the Jenyns fish (*Jenynsia lineata*), a small bony species found in Argentine rivers and popular with aquarists.

As shown in Fig. 4, the oviduct of the Indian sting-ray has its lining produced into long nutritive threads. Bundles of these pass into each embryo via the spiracles—breathing holes just behind the eyes—and secrete fluid into its stomach. The extent of this fluid's contribution is indicated by the fact that the organic matter in the egg increases from 0·2 to about 10·0 gm. during development.

Rather similar processes serve the developing Jenyns fish (Fig. 6) but there they are derived from the ovary. They force their way through one of the gill-chamber openings passing oxygen and probably food to the embryo. In addition, nutritive fluid secreted by the ovary is drawn in through the mouth. This fluid, incidentally, is strengthened by the autodigestion of some of the embryo which die and liquefy inside the ovary.

Probably most of these fishes growing inside their mothers have the capacity, when they are very small, to absorb liquid nutriment over the whole skin surface as well as through the yolk-sac wall. When their mouths open they begin to take fluid into the food canal and digest it.

As in the case of mammals, indigestible residues are stored until birth and never voided inside the female.

Some embryos are provided with special devices which considerably increase the absorptive surface of the skin. The rays of the dorsal and anal fins of developing surf-fish, for instance, are expanded at their ends into spoon-shaped absorptive organs (Fig. 7). Long absorptive ribbons springing from the ventral surface of the growing embryos of *Zoogeneticus quitzevensis* help in the gathering of nutriment from the ovarian fluid. Similar processes in the deep-sea (7000 ft.) viviparous fish *Parabrotula* almost certainly have the same functions.

A most intimate relationship between mother and embryo is seen in the American dogfish *Mustelus laevis*. There the embryos are in separate compartments in the wombs and each has its yolk-sac firmly attached to the maternal tissues. As Fig. 8 shows, finger-like processes of the sac burrow into the maternal tissues and there is a system for the transfer of food from the latter to the embryo. All this is reminiscent of the mammalian placenta and umbilical cord.

The eggs of this dogfish average only 5·5 gm. at the beginning of development. At birth the embryo scales 189 gm. or so, the increase in organic matter being very considerable.

Some workers reserve the term 'viviparous' for this condition in which the egg is intimately attached to the maternal wall. They style such forms as the spiny dogfish and surf-fish as 'ovo-viviparous'.

From the evolutionary standpoint, the condition seen in the American dogfish—it is also found in the blue shark (*Carcharias glaucus*) and a few other cartilaginous species—is the highest development of piscine viviparity. But it is not, apparently, the most efficient. Some of the ovo-viviparous forms which have nutritive threads hanging from the womb lining get more nutriment to their embryos. So do some of the bony species which have no structures comparable with the placenta of *Mustelus laevis*. The egg of the pigmy top minnow (*Heterandria formosa*), for instance, in which the yolk-sac is little more than a vestige, increases its dry weight from 0·017 mgm. or so to about 10 mgm. by the absorption of maternal juices. At the other end of the bony fish scale are forms like the Norway haddock (*Sebastes norvegius*) which produce fully developed young each with a lower dry weight than the egg from which it came (Fig. 5). This state of affairs, it will be remembered, occurs in the spiny dogfish.

A killifish of the Japanese ricefields—*Oryzias latipes*—might be said to be 'in an interesting condition' as it appears to be just developing the habit of viviparity. Sometimes the eggs are laid soon after fertilisation and develop outside the female's body. On other occasions they remain inside and have the power to grow there.

The period of gestation varies considerably with different species as it does in mammals. The Table gives the times for some common viviparous forms.

Fish	*Gestation Period*
Guppy	20 days
Violet sting-ray	2 months
Viviparous blenny	4 months
Electric ray	6 months
Spotted dogfish	7 months
Black-mouthed dogfish	9 months
Spiny dogfish	10 months
Blue shark	10 months

Labour appears to be a simple and rapid affair in fishes. The young are usually streamlined and there is never a dearth of liquid to lubricate the female passage. The New York ground shark (*Carcharhinus milberti*) is said to produce its young tail-first. At the birth of the spiny dogfish brood, the young certainly arrive head-first. (A tail-first delivery would be dangerous in this species as the backward directed dorsal spine might tear the uterine tissues.)

Eyewitnesses describe the female manta as leaping out of the water and emitting a single youngster in mid-air. Such an aerial birth has also been described for the spotted eagle ray (*Myliobatis aquila*).

The number of young in a brood varies from the single one of the manta to as many as a thousand in the Norway haddock. A tiger shark has been known to produce a brood of 57, whilst tope have been caught with 50 embryos inside them. Eleven is about the limit for the spiny dogfish.

Among other recorded figures are 3 to 20 for the surf-fish; 7 to 11 for the spiny dogfish; 20 to 25 for the mosquito fish (*Gambusia affinas*); 24 for the sawfish (*Pristis pectinatus*) 37 for the hammerhead shark (*Sphyrna zygaena*) and up to 300 for the viviparous blenny (*Zoarces viviparus*).

As would be expected, the bigger females of a given species have larger broods than the smaller ones. A four-eyed fish (*Anableps*), for instance, usually produces broods of four when it is 5 inches long, whilst an older specimen, 8 inches long, will give birth to as many as thirteen at a time. In this fish, incidentally, it is the alimentary canal which is the chief absorptive organ of nutrients for the ovarian fluid. Its middle section is enormously enlarged during gestation and deals with fluid taken in through the

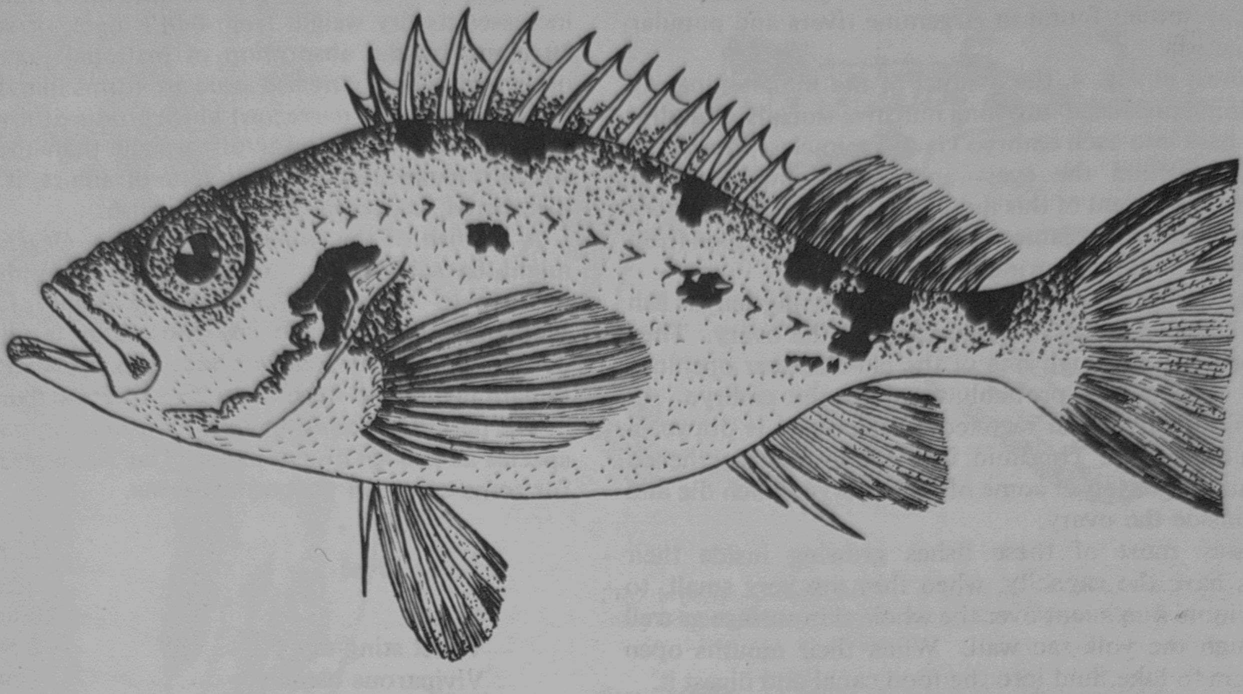
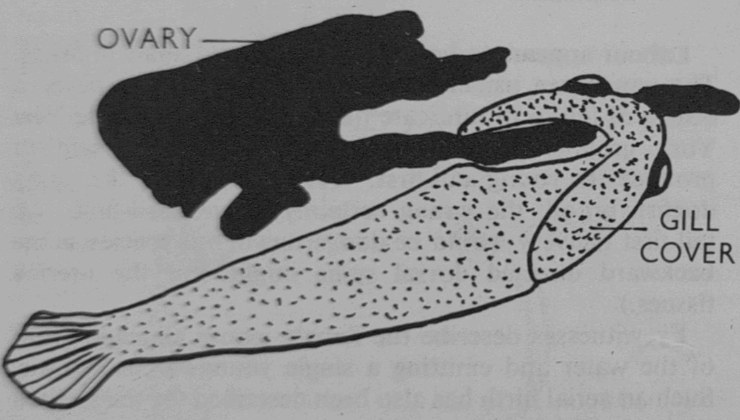


FIG. 5.—A Norway haddock—a viviparous species of northern waters which produces up to 1000 young at a time.



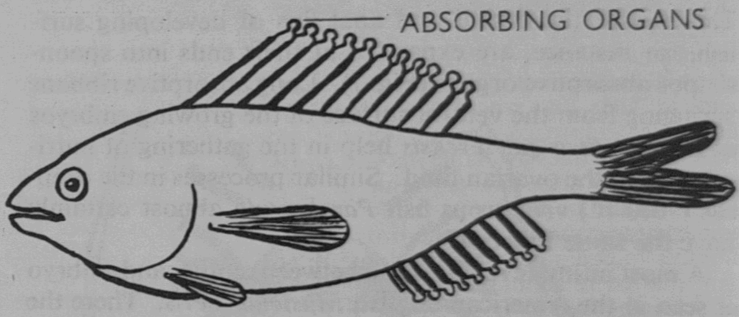
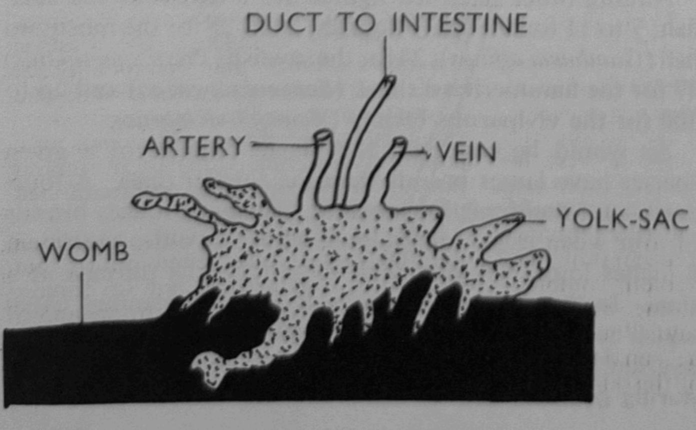


FIG. 7.—A surf-fish embryo showing the spoon-shaped ends of the dorsal and anal fins which serve as absorptive organs.

FIG. 6.—Embryo Jenyns fish with oxygen-bearing processes of the maternal ovary passing through the right gill chamber and mouth.

FIG. 8 (*below*).—Section through the wall of the womb of *Mustelus laevis*, showing the intimate insertion of the embryo's yolk-sac.



mouth. In addition, the outer wall of the yolk-sac is covered with absorptive papillae.

The ovaries of the four-eyed fish and of most other viviparous species soon reassume the virgin condition after the birth of a brood, and a considerable time elapses before the next impregnation. The females of some species, however, seem to pass their adult life in a state of almost permanent pregnancy. The moon minnow (*Platypoecilus maculatus*) of Central American swamps, for example, produces a new brood after an interval of only 30 days, whilst the pigmy top-minnow may carry up to eight broods at different stages of development at the same time. This superfoetation, as the multiple brood condition is called, is accomplished with the aid of sperms received at a single copulation, the male cells retaining their activity within the female's body for many months. Under ideal conditions of temperature the pigmy top-minnow can produce a perfect brood regularly every four days.

Far and Near

Awards to Inventors: £50,000 to Watson-Watt

THE LONG-AWAITED AWARDS to the scientists involved in the initiation and development of radar were announced recently. The Royal Commission on awards to World War II inventors gave £50,000 to Sir Robert Watson-Watt, prime mover in the radar project whose radiolocation work began with his neat technique for tracking thunderstorms by means of radio. The thrilling story of radar's development was told by Watson-Watt himself in DISCOVERY, September 1945 (p. 281). Probably the most revealing paragraph in that article read as follows: "The most important lesson for the future which is to be derived from the history and achievement of radar is not contained in the broadly true and gratifying statements that 'It may be claimed that radar saved the civilised world', that 'Radar has brought about the greatest revolution in naval tactics since the change from sail to steam', that 'Radar has, more than any single development since the airplane, changed the face of warfare'. The really important lesson is that it is far more essential in the national interest in peace and in war that there should be an adequate supply of flexible minds and flexible techniques available in the country than that any great concentration of these minds should be put on to the solution of immediate problems and the provision of immediate equipments. It is more important that there should be a large number of scientists free to nose around in other people's business, asking their own questions in their own way, than that there should be large establishments engaged on the production of pieces of equipment designed, however ingeniously and economically, to meet operational requirements that have already been formulated."

Corollary to Watson-Watt's insistence on flexibility is his frequently expressed fear that long-established research establishments tend to stifle that vital quality; a laboratory, like a living organism, tends to develop in such a way that a graph of its activity over the years (measured in terms of a simple index such as the laboratory's collective output of research papers or useful inventions) resembles a vital growth curve. Most laboratories tend to show a falling-off in both the quantity and quality of their research activities, a point which Watson-Watt learnt from bitter experience and which prompted him to remark that "It would be a good thing if we could destroy most laboratories after they've existed for ten years, and then restart their special line of research elsewhere and with fresh brains."

Other radar researchers to benefit from the Royal Commission's award are:

Mr. A. F. Wilkins awarded £12,000.
Mr. H. Larnder (£2,400).
Mr. P. E. Pollard (£1,200).
Dr. J. H. Mitchell (£750).
Mr. R. H. A. Carter (£750).
Mr. H. Dewhurst (£750).
Mr. S. Jefferson (£750).
Mr. B. Newsam (£750).
Mr. P. A. Marchant (£250, together with a further £250 jointly with Mr. D. A. Weir).

School Television Experiment

SIX SCHOOLS have been chosen to receive the first experimental television programmes for schools. They are: Albany Secondary Modern Boys' School, Chace Secondary Modern Girls' School, Higher Grade Selective Central Mixed School, Hazelbury Secondary Modern Girls' School (all four schools are at Edmonton); Arnos Secondary Modern Mixed School, Southgate; Trinity County School, Wood Green.

The vision signal for these experimental programmes will be transmitted from Alexandra Palace on a special wavelength, and the sound will be conveyed to the selected schools by land line. The programmes will be broadcast daily at 2.10 p.m. for four weeks, beginning on May 5.

The programmes will be designed for children of secondary school age. The twenty programmes will be grouped into five short series, dealing respectively with Science, Aesthetics, Current Affairs, Travel and the Industrial Scene. The main purpose of the experiment will be to try out a variety of programme techniques and to test their effectiveness for presenting educational material to children viewing in classrooms. The techniques will include the studio presentation of laboratory experiments and demonstrations; the use of animated diagrams and photomicrography; the presentation of film in many ways, including, for example, by a traveller who made it, or by a commentator on Current Affairs; outside broadcasts and feature programmes in which studio interview and demonstration will be combined with the showing of suitable film extracts.

Therapeutic Use of Paint

THE scientific use of colours is featured in the new Home for the Aged in Whitby, Ontario county. Painting the exterior and interior this way achieves the best in beauty and psychological effect, according to W. D. Sinclair, of the paint and varnish division of Canadian Industries Limited, who prepared the interior decoration plan for the home. "Proper colour combinations not only enhance the beauty of the surroundings," he says, "but have a definite therapeutic value—an important factor in an institution of this kind."

SIR ROBERT WATSON-WATT, *awarded £50,000 for his radar work, is seen here with his wife and scientific partner, Margaret, who in 1937 accompanied him on a walking tour through Germany sketching churches and other tall buildings that might have hidden radar installations.*

A similar, and very effective, use of coloured paints has been made in one London hospital, and the patients there are always impressed by the pleasing colour scheme which is based on soft and soothing colours and which seems revolutionary when compared with the garish 'barrack-room' colour schemes characteristic of most Victorian hospitals that are still run on nineteenth-century lines. The percentage of cures effected in this particular hospital is remarkably high and is undoubtedly due to painstaking attention paid by everyone on the staff of the hospital to all matters of detail, including such details as the colour of the paintwork and even the colour of the bed-screens. The medical profession is now beginning to realise that the harsh and crude primary colours which are suitable for painting machinery, buses and railway trains are calculated to delay the recovery of hospital patients, and the softer colours commonly used in house decoration are swiftly coming into favour for hospital decoration.

The Dome of Discovery

FOR six months the L.C.C. has been discussing what ought to be done with the Dome of Discovery, which cost £160,000, though long before the Festival of Britain opened the editor of DISCOVERY was assured that negotiations for its eventual purchase and transportation to Blackpool were virtually complete. The Festival organisers claimed that the roof of the Dome had been specially designed so that its dismantling and re-erection elsewhere should be an easy matter. There was also, about the same time, a persistent rumour that an American circus proprietor had made a bid for the Dome!

Now the Minister of Works has stated that the Dome must come down, and the L.C.C. has decided not to contest this ruling. It is planned to demolish the building and scrap the structural components. This scheme has been criticised by the Dome's designer, Mr.

Ralph Tubbs. He has said, "I feel it is rather tragic that the Dome should be scrapped. The L.C.C. never really got down to considering what to do with it. It would make a very good stadium. The only other building of similar size in Europe is the stadium at Zürich. It is so wasteful to scrap it as it was designed in such a way that it could easily be re-erected. It would cost only one-fourth of its value, or about £50,000, to reconstruct it elsewhere but its value as scrap metal is about £16,000. It will take about two months to take it down and in that time proposals could well be made. The sections have only to be loaded on to lorries and brought to a new site. The cost of reconstructing it would be exceedingly low for that type of building. The people of the North should have an opportunity of getting it, or some of the Midland towns might want it. You have 100,000 ft. of cover in the Dome and dismantling and moving it would work out at about 10*s.* a square foot, or half a year's rent for office space covering a similar area."

The majority opinion among the many people we have consulted about the most useful way of disposing of the Dome is that it is worth preserving, even though it may have to be moved from the South Bank site. There was, however, general agreement with the stricture of the Minister of Works implicit in his comment that he was "unwilling to become the caretaker of an empty and deteriorating structure". Many people seem to feel that there was a distinct danger of the Dome of Discovery becoming a white elephant like the Crystal Palace, the relic of the 1851 Exhibition, which eventually ended up as a warehouse for window-cleaning equipment.

Obituaries

SIR REGINALD EDWARD STRADLING, at Shrivenham, on January 26, aged 60. After serving as an R.E. officer in World War I, he lectured on civil engineering at Birmingham University and Bradford Technical College. In 1924 he became director of the D.S.I.R.'s Building Research Station at Garston, Herts.; in addition he looked after the Road Research Laboratory during the period 1933–9.

Civil defence was made his pigeon; as a great expert on buildings and explosives Stradling was appointed full-time 'adviser on structural considerations of A.R.P.' by Sir John Anderson, now Lord Waverley. Unfortunately war began before Stradling's plans for scientifically designed air-raid shelters could be given practical reality, and had it not been for brilliant improvisation by certain engineers Britain's civilian population would have been as ill-equipped to meet the German strafing of 1940 as the B.E.F. had been in France earlier that year. Stradling's next project involved the forming of a Civil Defence Research Committee, including such outside experts as Prof. J. D. Bernal. This committee studied many aspects of Civil Defence, but specialised in collecting and analysing information about damage caused by air raids. When the bombing of Germany's cities and industrial centres was planned by the R.A.F. team, this information was applied with devastating results.

The late SIR REGINALD STRADLING.

In 1944 Stradling went to the Ministry of Works to start 'operational research' into building methods which might help to reduce the post-war housing shortage. The Building Research Station was, of course, linked to this project. This work led to a great efflorescence of non-traditional building techniques, as for instance the erection of prefabricated metal school buildings from components made by aircraft firms.

Bad health forced Stradling to resign from the Ministry of Works in 1949, but after his recovery he became head of the Military College of Science at Shrivenham where "he was carrying out his new duties with his characteristic enthusiasm when death came to him suddenly" on January 26 1952, states *Nature*. He will long be remembered for his versatility and infectious enthusiasm. He leaves one son and one daughter, children of his marriage to Inda Pippard of Yeovil in 1918. His brother-in-law, A. J. S. Pippard, is Professor of Civil Engineering at the Imperial College of Science.

* * * *

The death is announced of SIR CYRIL S. FOX, former director of the Geological Survey of India, on December 28, 1951, at the age of 65. The Indian Journal *Science and Culture* reports that his death followed a few days after his arrival in India on a business visit.

Ministry of Agriculture Bulletin on Culinary and Medicinal Herbs

IN this country a large number of herbs are grown for culinary, medicinal, confectionery, perfumery and other purposes. There is a continuous demand on the wholesale markets for fresh herbs, and factories use large quantities for preparing dried kitchen herbs, sauces and pickles.

Full information about these crops is provided in the Ministry of Agriculture and Fisheries Bulletin No. 76.

The use of herb extracts for medicinal purposes lapsed during recent years, because supplies of chemicals from abroad were not easily obtained and chemists learned how to use inorganic chemicals to make 'synthetic' drugs. Since the beginning of the last war, however, drug manufacturers have found themselves cut off from many of their usual sources of supply, and the hitherto despised English wild plants are now regaining their earlier economic importance. Efforts are being made to establish the cultivation of drug-producing plants on a wider scale, and Bulletin No. 76 will be found invaluable by all growers interested in these crops.

Night Sky in April

The Moon.—Full moon occurs on April 10d 08h 53m, U.T., and new moon on April 24d 07h 27m. The following conjunctions with the moon take place:

April			
9d 20h	Saturn in conjunction with the moon	Saturn	7° N.
12d 11h	Mars ,,	Mars	7° N.
22d 16h	Mercury ,,	Mercury	6° S.
23d 04h	Venus ,,	Venus	6° S.

In addition to these conjunctions with the moon, Mercury is in conjunction with Venus on April 16d 19h, Mercury being 1°3′ N.

The Planets.—Mercury, in inferior conjunction with the sun on April 5, is too close to the sun to be seen in April. Venus is also too close to the sun for favourable observation in April. Mars rises at 21h 50m, 20h 40m, and 19h 15m, on April 1, 15 and 30 respectively. On April 23 the planet is very close to α Librae, after which it moves away in a westerly direction from the star. Jupiter sets an hour after the sun at the beginning of the month and is in conjunction with the sun on April 17, after which it becomes a morning star, rising shortly before the sun towards the end of the month. Saturn sets at 6h on April 1, 5h on April 15, and 4h on April 30, and is favourably placed for observation; it is in opposition to the sun on April 1 and during the month it sets about the time of sunrise, being visible during the greater portion of the night. It has been pointed out that Saturn is in conjunction with the moon on April 9; the moon rises on this night about 18h 12m and less than 2 hours later the bodies will make their close approach, Saturn being N. of the moon. It should be mentioned that, while summer time begins on the morning of April 20, no notice of this is taken in the above times and Greenwich Mean Time will always be used.

Those who are interested in meteors should be able to see the Lyrid shower from about April 18 to 24. The paths traced backwards appear to converge to a small area in the constellation of Hercules but close to the constellation Lyra, and hence the meteors are called the Lyrids. The brightest star in this constellation is Vega, and is easily recognised by its bluish-white colour. It is about 26 light-years distant, and as a light-year is 6 million million miles or 6 (English) billion miles the distance of Vega is nearly 160 billion miles. It is considerably more luminous than the sun—perhaps fifty times as great—and if we were on a planet belonging to this star our eyes as they are constructed could not endure the glare unless were we much farther off from Vega than we are from the sun.

Council for Nuclear Research set up in Geneva

A Council of Representatives responsible for planning an international laboratory and organising other forms of co-operation in nuclear research has been set up with headquarters in Geneva, after a five-day conference convened by Unesco in February. Nine states have already signed the agreement setting up the Council: Denmark, France, Germany, Greece, Italy, the Netherlands, Sweden, Switzerland and Yugoslavia. Two others —Belgium and Norway—are expected to sign shortly.

Each country will have one vote on the Council, but may send two delegates. This body, which will have an independent legal status, will conclude a special agreement with Unesco and will co-operate with that organisation. Its budget will total $200,000 to be contributed to by its member states. The Council's term of office will not exceed eighteen months, after which it will submit a report on the results of its work. It is expected that this will lead to a convention creating an International Nuclear Research Laboratory, the location of which will be decided later.

One task of the Council will be to organise a study group at the Copenhagen Institute for Theoretical Physics. This group will survey the present situation in atomic physics with special regard to the work to be undertaken by European co-operation. It will also study problems which may be tackled with equipment already in existence and to be operated on a European basis. It will endeavour to stimulate European collaboration by furthering contacts between scientists in different countries and by offering possibilities for younger physicists to take part in the research work carried on in the Copenhagen Institute.

The Council is to consider an offer from Liverpool University to provide special facilities for a number of European physicists to work there. This university has agreed to take four experimental physicists for at least one year, two cyclotron engineers for a shorter period, and one or two theoretical physicists.

Forty delegates and observers participated in the Geneva Conference. Among them were three Nobel prizewinners: Niels Bohr, of Denmark, Werner Heisenberg, of Germany, and Sir George Thomson, of the United Kingdom.

The Bookshelf

Carl Linnaeus. By Knut Hagberg. (London, Jonathan Cape, 1952, 264 pp., 18*s*.)

Science has never produced a more prodigious worker than Carl Linnaeus. A truly great natural philosopher, whose *Critica Botanica*, *Systema Naturae* and *Species Plantarum* revolutionised botany through his introduction of binomial nomenclature and the modern system of classification, was remarkable not merely as a scientist but as a man. Son of a clergyman, he went to school in Växjö, where he studied "the most outstanding scientific works of the age, especially on botany". After a year at Lund University, he went to Upsaala University where he became lecturer and demonstrator in the university's botanical garden. Following up Vaillant's theory concerning the sexuality of plants, he had already come to recognise the significance of stamens and pistils of flowers, which he saw to be no less distinctive than petals, and the dissertation (*Sexu Plantarum*) he wrote established him as the brightest student in Upsaala, although his fellow student, Peter Artedi, was "almost his equal in scientific talents". It should be noted that Linnaeus was then an *undergraduate*. It should also be noted that this thesis was as remarkable aesthetically as it was scientifically; his literary style was indeed a thing of beauty, being completely unaffected by the prevailing Swedish style of writing; according to Knut Hagberg, the style reminds one of early English poetry —"independent of all so-called trends, poets of every age have sung in this strain". The thesis, which was circulated among the students of Upsaala, opened the eyes of Olaf Rudbeck—a great zoologist whose best bird pictures rank with those of Audubon—to the real qualities of Linnaeus, already at that time the protégé of Dr. Olof Celsius. Encouraged by these two patrons, he went on to establish the outlines of a system for classifying plants—this work he completed as early as 1731, when he was only twenty-four years old.

Then came what was perhaps the happiest experience of his whole life—his expedition to Lapland. His account of his journey "depicts Lapland as an earthly paradise": to quote Linnaeus's own words, "The many diseases which exercise their tyranny elsewhere, especially in the courts, do not intrude here until old age has gathered ripe fruit. Envy casts no jaundiced eye here. Neither has power over the next man any profit, nor does the nobleman hold any estate in demesne. The kings themselves do not disturb the people's peace with edicts and decrees, for mischief here has not begun to rebel. To drudge by the sweat of one's brow, which has made slaves of both high and low, is here unknown." Though Linnaeus's own personal philosophy was essentially Epicurean, one finds his writing about Lapland are full of quotations from Virgil and Ovid; this apparent discordance was in fact no discordance at all, as Linnaeus was blessed with the kind of mind which can select truths that are timeless and universal when quoting from other men's writings.

The great *Systema Naturae*, first published in Holland in 1735, set the seal on his career. There is no need here to expatiate on the importance of this remarkable book, which was first printed when Linnaeus was twenty-eight years old, beyond quoting this brief pertinent passage from the biography under review: "For Linnaeus and his age all species were settled once and for all, created by God in the dawn of time. The classification into biological groups therefore meant something entirely different to Linnaeus from what it does to us. It meant that God, like a skilful weaver with warp and woof, produced a clear and lovely pattern, so arranged and fashioned in the natural objects—zoological, botanical and mineral—that a definite scheme must be apparent to the beholder. In this world of nature, defined for all time, there is a plan, a geometrical tendency." It should be recorded, however, that Linnaeus did in fact revise considerably his early ideas about the immutability of species. Horticultural varieties "produced by artificial means" exercised him a great deal; as this biographer says, "the Creator has permitted nature a kind of sportiveness" and (to quote Linnaeus) "*Therefore there are today two distinct differences between the plants: one a veritable difference, the multiplicity produced by the Almighty's . . . hand; but the other, variations in the outer shell, the work of nature in a moment of jest.*"

The gardeners' hybrids were temporary affairs, thought Linnaeus; if neglected these forms "glide away and vanish like fleeting shadows". Which shows that he was fully aware of the phenomenon of reversion. His original conception of species he never held to be sacred and immutable: indeed "*Hardly has he completed his system, hardly has he seen it universally accepted and hailed with delight, than he is prepared to question its very foundation. Jealous as he may have been of his work, he was even more so of the truth. And in the history of science, and human thought . . . he stands far more alone in this than most people imagine.*"

This biography completely disposes of the misconception that Linnaeus was the forerunner of the modern herbarium keeper; it was the *living plants* that Linnaeus studied, and the natural plant associations, not just the artificial associations characteristic of modern botanic gardens.

His sense of ecology was well developed, and he was always conscious of such things as food chains; to him, all flesh is grass, and he described very clearly the natural cycle involving herbivorous animals and carnivorous animals and the conversion of faeces and animal bodies into substances capable of feeding plants. The concept of the 'food chain' is very clearly explained by him.

There is no room here to do justice to Linnaeus's philosophy of life, nor his sociological observations. Nor can one do more than mention that Linnaeus was a great wit; some of his 'wisecracks' were as clever as anything written by Bernard Shaw, though he was fundamentally a wiser and more sensitive person than Shaw.

After reading this volume no one will be surprised to find the author describing the eighteenth century as Sweden's 'Linnean Age'; this was indeed the Golden

Age of Swedish culture, and Linnaeus was the greatest man that that age produced. One realises with a shock that if Linnaeus had lived in the twentieth century he would, most probably, have been ignored by the selectors of the Nobel prizewinners!

WILLIAM E. DICK

Modern Science and its Philosophy. By Philipp Frank. (Cambridge, Mass., Harvard University Press; London, Geoffrey Cumberlege, 324 pp., 36*s*.)

THIS is a book of sixteen independent essays, all of which originally appeared in various journals, together with a long introduction written specially for this volume. The first essay dates from as long ago as 1907, though the last fourteen are post-1930. The latest was written in 1947. Eight of them have already been re-published in *Between Physics and Philosophy* (Harvard University Press, 1941). Dr. Frank himself, after receiving his early training in physics in Vienna and at one time holding a chair in Prague, is now Faculty Lecturer on Physics and Mathematics at Harvard.

The thesis that forms the theme of the whole collection is that scientific theories are not statements about a real world of Nature, but are statements by means of which observed correlations may be conveniently summarised. The historical genesis of this view Frank traces in the long introduction, showing how its true modern founder was Ernst Mach, whose philosophy was developed logically and given a polemical edge by the Vienna Circle. A similar view was maintained by William James. As Bergson put it, "whereas for the other conceptions a new truth is a discovery, for pragmatism it is an invention". Scientific theories accordingly are not ontology. "In a hypothesis one can only state a conjecture about future experiences, not about the real existence of a thing corresponding to an assigned name."

The most interesting essays in the collection are those devoted to the discussion of some outstanding occasions on which the assumption that scientific theories make ontological statements has produced confusion within science and conflict between a new scientific theory and established philosophical and theological opinions. One of the most interesting of them concerns "the philosophic meaning of the Copernican revolution", a theme which runs through several essays, and to which Pierre Duhem devoted a profound and stimulating series of papers published in 1908 in the *Annales de philosophie chrétienne* under the title "Σῴζειν τὰ φαινεόμενα". Frank compares the reception of Copernicus's theory with that of Einstein's, and shows how both theories were initially opposed by those who held that they were 'philosophically absurd' because they contradicted certain propositions from the theories they replaced to which an ontological meaning had been given. The same pattern is traced in other essays, through the history of the quantum theory, through the arguments about causality and about determinism and indeterminism in modern physics, and through the attempt on the one hand by 'idealists' like the late Sir James Jeans and on the other by Marxists to see in the changes in twentieth-century physics support for, or a threat to, 'spiritualist' or 'materialist' ontologies as the case may be. As Frank points out, relativity and the quantum theory have in fact introduced nothing new into this field. In the seventeenth and eighteenth centuries there were parallel ontological 'interpretations' of Newton's mechanics, and these led to parallel controversies. In the end the acceptance of a new theory destroys the ontology erected upon the old, and for those prepared to learn the philosophical lesson of the process it destroys such ontology altogether. "By knowing the origin of philosophic principles we need not be terrorised by the verdict 'philosophically false'. It means only that the new physical laws are in contradiction with the old physical laws which appear now disguised as philosophic principles with pretensions of eternal validity. The old physical theory was a good description of a restricted group of facts. But to cover the new facts the old theory became inconvenient. It is natural to drop it, if an obsolete physical theory does not pretend to be an 'eternal philosophy'. This very simple state of affairs has often been described by the pretentious term 'crisis of physics', or even 'crisis of science'."

There cannot be many scientists now who would not accept the essence of this sedate conclusion, and a qualification that would have to be made in recommending this book to readers is that it is frequently obvious, nearly always dull, and often also irritatingly repetitive. Nowhere in these matt pages is to be found the bright interest of a number of other contemporary writers who have built their philosophy upon an analysis of science. And nowhere is there the slightest suggestion that this method of constructing a general philosophy has ever been criticised. For example, Frank accepts the logical positivist 'verification principle' without question, and he also asserts the orthodox doctrine of his school that "we have to teach our students how to eliminate all statements that are neither propositions describing the result of an observation, nor propositions that are part of a logical conclusion". Then how is he to avoid eliminating the verification principle itself? Again, he is, if he wishes, at liberty to use the word 'metaphysics' to mean "direct interpretation of the basic principles of science in terms of common sense or everyday experience". But his intelligent criticism of this kind of 'metaphysics' has nothing to do with metaphysics or ontology, in the sense of inevitable postulates, to which some recent logicians have been led. Nowhere from Frank's pages would one discover that logical positivism had come to grief when trying to apply to ethics methods of proven success in physics. Instead, we are given in two essays dealing with the place of the philosophy of science in practical education a superficial and tendentious 'socio-psychological analysis' of religious and philosophical relief, concentrating mainly on dialectical materialism and what seems to be an extremely naive form of 'Thomism'.

In short, the virtues of this book are in the many illustrations which Frank has given of the need for scientists to think philosophically, for to neglect to do so is, in Whitehead's phrase, "to assume the correctness of the chance philosophical prejudices imbibed from a nurse or a schoolmaster or current modes of expression". Moreover, he shows clearly that the value of philosophical thinking to the scientist is seldom to help him to advance his purely scientific work, but rather to defend it from irrelevant objections and bogus metaphysics—he might have added also to defend other philosophical disciplines from bogus science. The defects of the book are the author's apparent ignorance of the variety of philosophical questions that there are, including that concerning the foundations of his own system. Perhaps these defects, as he honestly writes, are "determined by my own background, scientific and personal".

A. C. CROMBIE

Hutchinson's Pocket Technical Encyclopaedia. Compiled by L. E. C. Hughes and Jean P. Bremner. (London, Hutchinson's Scientific and Technical Publications, 1952, 182 pp., 7*s*. 6*d*.)

UNINTELLIGIBILITY is a besetting sin of current scientific and technical literature. One reason for this fault is a failure on the part of the authors to understand basic considerations of the grammar and syntax of the language in which they write (as evidenced, for example, by the almost complete absence of *verbs*, *adjectives* and *adverbs*). Another reason is the haste with which new technical terms are coined; thus, for instance, one finds new words produced by crossing one Latin word with one Greek word, without any regard to the original meanings of the words, so that many technical terms carry meanings which are etymologically impossible. Then there is the unrestrained use of symbols. The final result is that many research papers have the appearance of having been written in code, and until machines have been invented which are capable of decoding or translating such papers they promise to go unread and unwept (and even unpublished) in the journals of erudite societies.

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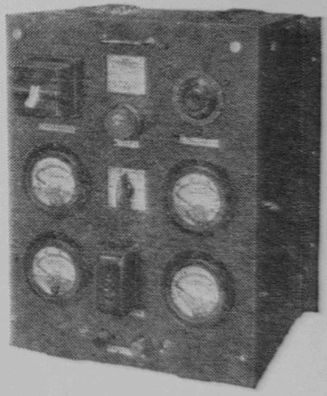

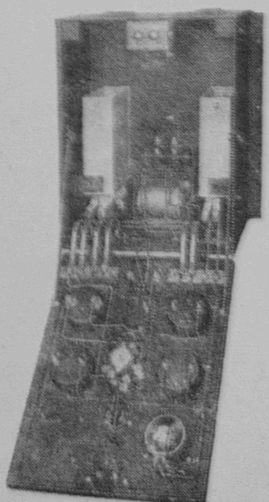

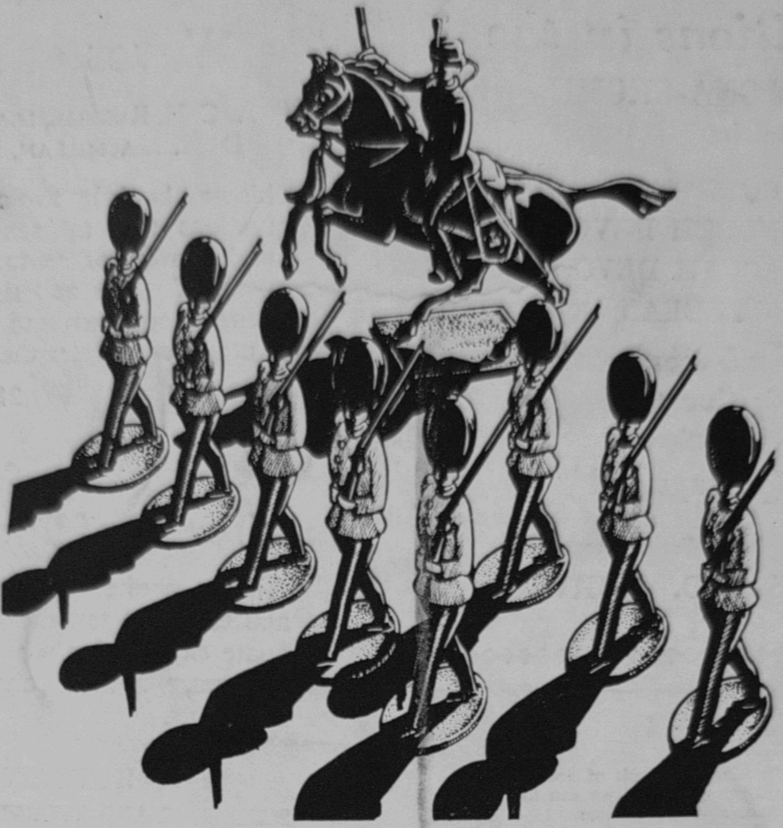

LEAD

LEAD, one of the heaviest of the elements, is found in many parts of the world as galena or sulphide of lead. It is still mined in Northern England and in Wales. Lead was one of the first metals to be worked by Man. The Baths of ancient Rome were supplied with water through pipes made of lead, and for centuries it has been used as a roofing material. Soft, easy to shape and resistant to corrosion, lead is still employed for these purposes, but today it has many other important uses. Large quantities alloyed with antimony are now used to make plates for electric accumulators and to protect insulated cables. Soft solder is an alloy of lead and tin, and alloys of copper, tin and lead are used for bearings. Litharge, an oxide of lead, is used in making flint glass, pottery glazes and in the processing of rubber. Red lead, another oxide, and white lead, or lead carbonate are well known in the manufacture of paint. In the chemical industry, plant and equipment for the manufacture and storage of sulphuric acid are lined with lead because of its resistance to corrosion. I.C.I. makes wrought lead products such as sheet, pipes, tape and wire for a wide variety of purposes. It also makes the compounds, lead-azide and lead-styphnate for the detonators used with blasting explosives in mining and quarrying.